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NEW CONSTRUCTIONS IN GRAPHICAL STATICS.

By HENRY T. EDDY, C. E., Ph. D., University of Cincinnati.

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III.

ARCH RIB WITH FIXED ENDS AND HINGE JOINT AT THE CROWN.

Let the curve a of Fig. 3 represent the proportions of the arch we shall use to illustrate the method to be applied to arches of this character. The arch a is segmental in shape, and has a rise of one-fifth of the span. It is unnecessary to assume the particular dimensions in feet, as the above ratio is sufficient to determine the shape of the arch.

The arch is supposed to be fixed in the abutments, in such a manner that the position of a line drawn tangent to the curve a at either abutment is not changed in direction by any deflection which the arch may undergo. At the crown, however, is a joint, which is perfectly free to turn, and which will, then, not allow the propagation of any bending moment from one side to the other. In order that we may effect the construction more accurately, let us multiply the ordinates of the curve a by some convenient number, say 2, though a still larger multiplier would conduce to greater accuracy. We thus obtain the polygon d.

Having divided the span b into twelve equal parts b_1 b_2, etc, (a larger number of parts would be better for the discussion of an actual case), we lay off below the horizontal line b on the end verticals, lengths express on some assumed scale the which weights which may be supposed to be concentrated at the points of division of the arch. If $a\,l$ is the depth of the loading on the left and $al' = \frac{1}{2}al$ that on the right, then $b_6 w_1 + b_6' w_6' =$ the weight concentrated at a; $w_1 w_2 =$ the weight at a_1; $w_1' w_2' =$ the weight at a_1', etc. Using b as a pole, draw the equilibrium polygon c, whose extremities c_6 and c_6' bisect $w_2 w_4$ and $w_3' w_4'$ respectively.

Now to find the closing line of this equilibrium polygon so that its ordinates shall be proportional to the bending moments of a straight girder of the same span, and of a uniform moment of inertia I, which is built in horizontally at the ends and has a hinge joint at its center; we notice in the first place that the bending moment at the hinge is zero, and hence the ordinate of the equilibrium polygon at this point vanishes. The closing line then passes through b the point in question. Furthermore it is evident that if we consider the parts of the girder at the right and left of the center as two separate girders whose ends are joined at the center, these ends have each the same deflection, by reason of this connection.

This is expressed by means of our equations by saying that $\Sigma(Mx)$ when the summation is extended from one end to the center is equal to $\Sigma(Mx)$ when the summation is extended from the other end to the center, for these are then the respective deflections of the center. We may then write it thus :

$$\Sigma_{b_6}^{b}(Mx) = \Sigma_{b_6'}^{b}(Mx)$$

The equation has this meaning, viz : that the center of gravity of the right and left moment areas taken together is in the center vertical : for, taking each moment M as a weight, x is its arm, and Mx its moment about the center.

In order to find in what direction to draw the closing line through b so that it shall cause the moment areas together to have their center of gravity in the center vertical through b, let us draw a second equilibrium polygon using the moment areas as a species of loading.

The area on the left included between any assumed closing line as bb_6 (or bh_6) and the polygon bc_6 may be considered to consist of a positive triangular area bc_6b_6 (or bc_6h_6) and a negative parabolic area $bc_3c_6c_6$; and similarly on the right a positive area $bc_6'b_6'$ (or $bc_6'h_6'$) and a negative area $bc_3'c_6'c_6'$.

At any convenient equal distances from the center as at p and p', lay off these loads to some convenient scale. It is, perhaps, most convenient to reduce the moment areas to equivalent triangles having each a base equal to half the span: then take the altitudes of the triangles as the loads. This we have done, so that $pp_1 = \frac{1}{2}c_0c_3$, and $p'p_1' = \frac{1}{2}c_0'c_3'$. Now assume, for the instant, that closing line is b_6b_6', which of course is incorrect, and make $p_1p_3 = b_6c_6$ and $p_1'p_3' = b_6'c_6'$, then these are the loads due to the positive triangular areas at the left and right respectively, while pp_1 and $p'p_1'$ are the negative parabolic loads.

Take o' as the pole of these loads, then pp' may be taken for the first side of the second equilibrium polygon. Draw $pg \parallel o'p_1$ and $p'g' \parallel o'p_1'$, and then from g and g' draw parallels to $o'p_3'$ respectively. These last sides intersect at g_3. The vertical through g_3 then contains the center of gravity of the moment areas when $b_6\ b_6'$ is assumed as the closing line.

A few trials will enable us to find the position of the closing line which causes the center of gravity to fall on the center vertical. We are able to conduct these trials so as to lead at once to the required closing line as follows. Since, evidently, $b_6c_6 + b_6'c_6' = h_6c_6 + h_6'c_6'$, it is seen that the sum of the positive loads is constant. Therefore make $p_2p_3 = p_2'p_3'$ and use p_1p_2 and $p_1'p_3'$ as the positive loads, in the same manner as we used p_1p_2 and $p'_1p'_2$ previously.

This will be equivalent to assuming a new position of the closing line. The only change in the second equilibrium polygon will be in the position of the last two sides. These must now be drawn parallel to $o'p_2$ and $o'p_3'$ respectively; and they intersect at g_2. The vertical through g_2 contains the center of gravity for this assumed closing line. Another trial gives us g_4.

Now if the direction of the closing line had changed gradually, then the intersection of the last sides of the second equilibrium polygon would have described a curve through g_2, g_3 and g_4. If one of these points, as g_3, is near the center vertical, then the arc of a circle g_2g_3 g_4, will intersect it at g_5 indefinitely near to the point where the true locus of the points of intersection would intersect the center vertical.

Let us assume that g_5 is then determined with sufficient exactness by the circular arc $g_2g_3g_4$, and draw gg_5 and $g'g_5$ as the last two sides of the second equilibrium polygon. Now draw $o'p_5 \parallel gg_5$ and $o'p_5' \parallel g'g_5$, then $p_1p_5 = c_6h_6$ and $p_1'p_5' = c_6'h_6'$ are the required positive loads, and h_6bh_6' is the position of the closing line such that the center of gravity of the moment areas is in the center vertical.

It is evident that the closing line of the polygon d considered as itself an equilibrium polygon is the horizontal line through d, for that will cause the center of gravity of the moment areas on the left and right, between it and the polygon d, to fall on the center vertical.

The next step in the construction is to apply Prop. IV, for the determination of the bending moments.

That Prop. IV is true for an arch of this kind is evident; for, the loading causes bending moments proportional to the ordinates h_2c_2, h_3c_3, etc., while the arch

itself is fitted to neutralize in virtue of its shape moments which are proportional to k_2d_2, k_3d_3, etc. The differences of the moments represented by these ordinates are what actually produce bending in the arch.

Now the ordinates of the type hc are not drawn to the same scale as those of the type kd, for each was assumed regardless of the other. In order that we may find the ratio in which the ordinates hc must be changed to lay them off on the same scale as kd it is necessary to use another equation of condition imposed by the nature of the joint and supports, viz:

$$\Sigma^{a}_{b_6}(M_a - M_c)y = \Sigma^{a}_{b_6'}(M_a - M_c)y$$

or $$\Sigma^{d}_{b_6}(M_d - M_c)y = \Sigma^{d}_{b_6'}(M_d - M_c)y$$

The left hand side of the eq. is the horizontal displacement (*i.e.*, the total deflection) of the extremity a of the left half of the arch, due to the actual bending moments $(M_d - M_c)$ acting upon it: and the right hand side is the horizontal displacement of a the extremity of the right half of the arch due to the moments actually bending it. These are equal because connected by the joint.

The construction of the deflection curves due to these moments will enable us to find the desired ratio.

The ordinates kd and hc are rather longer than can be used conveniently, to represent the intensity of the moments concentrated at d_1, d_2, etc, and c_1, c_2, etc.: so we will use the halves of these quantities instead. Therefore lay off $dm_6 = \frac{1}{4}k_2b_6$, $m_6m_5 = \frac{1}{2}k_6d_5$, $m_5m_4 = \frac{1}{2}k_4d_4$, etc., and also $dn_6 = \frac{1}{4}h_6c_6$, $n_6n_5 = \frac{1}{2}p_5c_5$, etc.

We use only one-quarter of each end ordinate because the moment area supposed to be concentrated at each end has only one half the width of the moment areas concentrated at the remaining points of division.

Using b as a pole we find the deflection curve fb due to the moment M_a or M_d and the deflection curve gb due to the moments M_c on the left. On the right we should find a deflection $df' = df$ not drawn, and similarly a deflection dg' not equal to dg.

Now the equation we are using requires that the ordinates hc shall be elongated so that when used as weights the deflections shall be identical: *i.e.*, we must have $df = \frac{1}{2}gg'$. To effect the elongation, lay off $aj = df$ and $ai = \frac{1}{2}gg'$; and at any convenient distance on the horizontals ii_0 and jj_0 draw the vertical i_0j_0; then the lines ai_0 and aj_0 will effect the required elongation. For example, lay off $ai_6 = h_6c_6$, from which we obtain $aj_6 = k_6l_6$ for the left end ordinate, and similarly $aj_6' = k_6'l_6'$.

The pole distance tt_1, of the original polygon c must be shortened in the same ratio in which the ordinates are elongated. Hence the new pole distance of the polygon e is tt_2.

Since k_6k_6' is the closing line of the polygon e, and is horizontal, the pole of e is o, on the horizontal through h_6; for, h_6w_6 is the part of the applied weight sustained by the left support.

Now if the weight line be moved up to t_2 so that the applied weights are u_1u_1' at the center, etc., and o is the pole, the polygon e may be described starting from d, and it will finally cut off the end ordinates k_6e_6 and $k_6'e_6'$ before obtained. Then will the ordinates of the type de be proportional to the moments actually bending the arch, and the moments will be equal to the products of de by tt_2, in which de is measured on the scale of distance, and tt_2 on the scale adopted for the weights w_1w_2, etc.

The accuracy of the construction is finally tested by taking $\Sigma(ds)^2 = 0$, an equation deduced from $\Sigma^{w}(M_d - M_c)y = 0$, as explained in the previous article upon the St. Louis Arch. It is unnecessary to explain the details of this construction since as appears from Fig. 3 it is in all respects like that in Fig. 2.

Now let us find the intensity of the tangential compression along the arch and of the shearing normal to the arch. Since the pole distance tt_2 refers to the difference of ordinates between the polygons d and e, whose ordinates are double the actual ordinates, if we wish now to return to the actual arch a whose ordinates are halves of the ordinates of d, we must take a pole distance $tt_3 = 2tt_2$ and move the weight line so that it is the vertical through t_3. Then tt_3 is the actual horizontal thrust of this arch due to the weights; and ov_6 is the resultant stress in the segment a_6b_6 of the arch, which may be resolved into two components or_6 and v_6r_6 respectively parallel and perpendicular to a_6b_6.

Then are or_6 and v_6r_6 respectively, the thrust directly along, and the shear directly across the segment a_6b_6 of the arch. Similarly or_5 and v_5r_5 represent the thrust along, and the shear across the segment a_5a_4, and so on for other segments. These quantities are all measured in the same scale as that of the applied weights.

The shear changes sign twice, as will be seen from inspection of the directions in which the quantities of the type vr are drawn. The shear is zero wherever the curves d and e are parallel to each other. Thus the shear is nearly zero at b_6, at a_2 and at some point between a_2' and a_3'.

The maxima and minima shearing stresses are to be found where the inclination between the tangents to the curves d and e are greatest.

The statements made in the previous article, respecting the position of the moving load which causes maximum bending moments, are applicable to this kind of arch also.

The maximum normal shearing stress will occur for the parts of the arch near the center, when the moving load is near its present position, covering one half of the arch. But the maximum normal shearing stress near the ends, may occur when the arch is entirely covered by the moving load, or when it may occur when the moving load is near its present position, it being dependent upon the rise of the arch, and the ratio between the moving and permanent load.

The maximum tangential compressions occur when the moving load covers the entire arch. The stresses obtained by the foregoing constructions, go upon the supposition that the arch has a constant cross-section, so that its moment of inertia does not vary, and no account is taken of the stresses caused by any changes of the length of the arch rib, due to variations of temperature or other causes. These latter stresses we shall now investigate for both of the kinds of arches which have been treated.

TEMPERATURE STRAINS.

It is convenient to classify all strains and stresses arising from a variation in the length of the arch, under the head of temperature, as such stresses could evidently have been brought about by suitable variations of temperature.

The stresses of this kind which are of sufficient magnitude to be worthy of consideration, besides temperature stresses are of two kinds, viz. the elastic shortening of the arch under the compression to which it is subjected, and the yielding of the abutments, under the horizontal thrust applied to them by the arch. This latter may be elastic or otherwise. It was, I believe, neglected in the computation of the St. Louis Arch, and no doubt with sufficient reason, as the other stresses of this kind were estimated with a sufficient margin to cover this also. Some one has ignorantly suggested that barometric variations have a large effect. But it is believed that there are no other causes than those enumerated which have an appreciable effect.

Taking the coefficient of expansion of steel as ordinarily given, a change of $\pm 80°$F. from the mean temperature would cause the St. Louis Arch to be fitted to a span of about $3\frac{1}{4}$ inches, greater or less than at the mean.

The problem we wish to solve then is very approximately this: What horizontal thrust must be applied to increase or decrease the span of this arch by $3\frac{1}{4}$ inches, and what other stresses are induced by this thrust. In Fig. 4 the half span is represented on the same scale as in Fig. 2. The only forces applied to the half arch are an unknown horizontal thrust H at b_6 and an equal opposite thrust H at a. The arch is in the same condition as it would be if Fig. 4 represented half of a gothic arch of a span $= 2ab$, of which a was one abutment, and b_6 was the new crown at which a weight of $2H$ was applied. The gothic arch would be continuous at the crown, but the abutment a would be mounted on rollers, so that although the direction of a tangent at a could not be changed, nevertheless the abutment could afford no resistance to keep the ends from moving apart, *i.e.* there is no thrust in the direction of ab, any more than there is along an ordinary straight girder.

In order to facilitate the accurate construction, let us multiply the ordinates of a by 3 and use the polygon d instead. Now the real equilibrium polygon of the applied forces H, is the straight line kk_6. By real equilibrium polygon is meant,

that one which has for its pole distance, the actual thrust of the arch. As we are now considering this arch, H is the applied force, and the thrust spoken of is at right angles to H. We have just shown this thrust to be zero. We have then to construct an equilibrium polygon for the applied force H with a pole distance of zero. The polygon is infinitely deep in the direction of H, and hence is a line parallel to H. This fixes its direction.

Its position is fixed from the consideration that the total bending is zero, (because the direction of the tangents at the extremities a and b_s are unchanged), which is expressed by the equation

$$\Sigma(M_d)=0.$$

This gives us the same closing line through k which we found in Fig. 2, and the ordinates of the type kd, are proportional to the moments caused by the horizontal thrust H.

Now lay off $dm_s=\frac{1}{2}k_sb_s$, $m_sm_1=k_1d_1$, etc., as in Fig. 2.

The problem of finally determining H, will be solved in two steps, 1° we shall find the actual values of the moments to which the ordinates kd are proportional, and 2° find H by dividing either of these moments by its arm.

By considering the equation

$$D_yEI=\Sigma(My)$$

given in our first article, in which D_y is the horizontal displacement, it is seen that if the actual moments are used for weights, and EI for the pole distance, we shall obtain, as the second equilibrium polygon, a deflection curve whose ordinates are the actual deflections due to the moments. By actual moments, actual deflections, etc, is meant, that all of the quantities in the equation are laid off to the scale of distance, say *one* n^{th} of the actual size.

Now let the equation be written

$$nD_y\cdot\frac{1}{n}EI=\Sigma(My).$$

From which it is seen that if the ordinates be multiplied by n, so that on the paper they are of the same size as in the arch, we must use *one* n^{th} of the former pole distance, all else remaining unchanged.

Now for the St. Louis Arch, $EI=$ 39680000 foot tons. Let us take 100 tons to the inch, as the scale of force: and since $bd=3$ inches, the scale of distance n is found from the proportion 3 inches, $:\!:$ 51.8 ft. $:\!:$ 1 : $n=210$ nearly, and $EI\div 100\,n^3=9$ in. nearly, which is the pole distance necessary to use with the actual deflection one half of $3\frac{1}{4}$ in.$=1\frac{5}{8}$in., in order that the moments may be measured to scale. As it is inconvenient to use so large a distance as 9 in. on our paper, let us take $\frac{8}{9}$ of 9 in. $=3\frac{1}{3}$ in. nearly $=dz$ for the pole distance, and $\frac{8}{9}$ of $1\frac{5}{8}$ in. $=4\frac{1}{3}$ in. $=dy$, for the deflection.

Now with z as a pole and the weights dm_s, m_sm_1, etc, draw the deflection curve bf, having the deflection $=df$. The moments M_d must be increased in such a ratio that the deflection will be increased from df to dy. Therefore draw the straight lines bf and by, which will enable us to effect the increase in the required ratio. For example, the moment $dm_1=bi$ is increased to bj, and $dm_s=bj$ is increased to bj_s. Now measuring bj in inches and multiplying by 210 and by 100, we have found that 21000 $bj=1809$ foot tons$=$the moment at d or a.

And again, 21000 $bj_s=3747$ foot tons $=$the moment at b_s.

By measurement 210 $dk=17$ ft. and 210 $bk=34.8$ ft.

$\therefore$ $H=1809\div 17=106$ tons, +

or $H=3747\div 34.8=108$ tons $-$.

These results should be identical, and the difference between them of less than 2 per cent. is due to the error occasioned by using the polygon d instead of the curve of the ellipse, and to small errors in measurement. With a larger figure and the subdivision of the span into a greater number of parts this error could be reduced. The value of H found for the St. Louis Arch by computation was 104 tons, but that was not on the supposition of a uniform moment of inertia I, and should be less than the value we have obtained.

Now this horizontal thrust H due to temperature and any other thrusts of like nature due to compression, etc, is of the nature of a correction to the thrust due to the applied weights. Thus in Fig. 2 we found $3ov'$ to be the thrust due to the applied weights, and on applying the correction we must use the two thrusts $3ov'+H$ and $3ov'-H$ as pole dis-

tances to obtain equilibrium polygons whose ordinates reckoned from the arch a will, when multiplied by its pole distance, give the true bending moments. The tangential and normal stresses can then be determined by resolution, precisely as in Fig. 3.

If it, however, appears desirable to compute separately the strains due to H, this may be more readily done than in combination with the stresses already obtained. We have already seen sufficiently how the bending moments due to H are found. In fact the moments are such as would be produced by applying H at the point where the horizontal through k cuts the polygon d, for this is the point of no moment, and may be considered for the instant as a free end of each segment, to each of which H is applied causing the moments due to its arm and intensity.

To find the tangential stress and shear, lay off in Fig. 4 $av = H$ and on it as a diameter describe a semicircle, and draw $ar_6 \parallel a_7a_6$, $ar_7 \parallel a_6a_7$ etc.; then will ar_6 be the component of H along a_7a_6, and vr_6 be the component of H directly across the same segment. In a similar manner the quantities of which ar on the type are tangential stresses and the quantities vr are shearing stresses.

The scale used for this last construction is about fifty tons to the inch.

Now H is positive or negative according as the temperature is increased above or diminished below the mean, and these tangential and normal components, of course, change sign with H.

It should also be noticed in this connection that thrusts and bending moments, which are numerically equal but of opposite sign, are induced by equal contractions and expansions.

The stresses due to variation of temperature in the arch of Fig. 3, having a center joint, are constructed in Fig. 5.

It is evident from reasoning similar to that employed for the case just discussed, that the closing line dk_6 of the polygon d is the equilibrium polygon of the thrust H induced by variation of temperature. Suppose we have changed the equation of deflections to the form,

$$mD_y \cdot \frac{EI}{mn^2} = \Sigma\left(\frac{M}{n} \cdot \frac{y}{n}\right),$$

in which, if $mD_y = dy$ and $EI \div mn^2 = dz$, then the moments M and the ordinates y will be laid off on the scale of 1 to n. This is equivalent to doing what was done in the previous case, where m was equal to $\frac{1}{2}$. The remainder of the process is that previously employed.

It should be noticed that we have in Figs. 4 and 5, incidentally discussed two new forms of arches, viz: in Fig. 4 that of an arch having its ends fixed in direction, but not in position; *i.e.*, its ends may slide but not turn, and in Fig. 5, that of an arch sliding freely and turning freely at the ends. The first of these arches has the same bending moments as a straight girder, fixed in direction at the ends, and the second of them has the same bending moments as a simple girder supported at its ends.

UNSYMMETRICAL ARCHES.

The constructions which have been given have been simplified somewhat by the symmetry of the right and left hand halves of the arch, but the methods which have been used are equally applicable if such symmetry does not exist, as it does not, if, for example, the abutments are of different heights.

In particular, for the unsymmetrical arch, its closing line is not in general horizontal, and must be found precisely as that for the equilibrium polygon due to the applied weights.

If, in Fig. 3, the hinge joint is not situated at the center, the arch is unsymmetrical, and the determination of the closing line due to the applied weights, is not quite so simple as in Fig. 3. It will be necessary to draw the trial lines through the joint by which the curve of errors g is found.

SMOULDERING FIRES IN COAL MINES.—At the February meeting of the Manchester Geological Society a discussion arose as to the probable connection between smouldering fires in goafs in coal mines and mine explosions. It was observed that eighty per cent. of the explosions occurred between November and February, though it might be thought that the ventilation being slacker in the summer they would be more numerous. Mr. Greenwell thought it was very possibly the result of fire standing in a goaf.

ON BEAMS OF UNIFORM RESISTANCE, THE BEAM FORMING PART OF THE LOADING.

By S. W. ROBINSON, Professor of Mechanical Engineering in the Illinois Industrial University.

Written for Van Nostrand's Engineering Magazine.

In Professor De Volson Wood's admirable text-book on the "Strength of Materials," a chapter is devoted to beams of uniform resistance in which there appear a few novel solutions where the beam itself constitutes the entire loading. Though in a practical point of view, such solutions may seem to possess but little merit, yet in theory they are of much interest; and we know not how soon they may be extended to practical utility.

In the chapter just cited, a few pages following the solutions above referred to, we find the following, under the topic, "Unsolved Problems," viz.: "5. Required the form of a beam of uniform strength, which is supported at the ends, the weight of the beam being the only load. Suppose, also, that it is loaded at the middle." These two cases, as well as several others, are considered in the following solutions:

The present article is confined to the two modes of securing the beam: first, fixed at one end, and free at the other; and second, supported at both ends. In both of these the loading is of three different kinds: first, the beam itself; second, a concentrated load; and third, a uniformly distributed load. The form of beam is limited in three ways: first, depth constant; second, breadth constant; and third, depth divided by breadth constant, or sections similar.

The notation adopted is that of Prof. Wood's book, where

R = modulus of rupture.

b = greatest breadth of beam.

d = greatest depth of beam.

l = length of beam.

δ = weight of unit of volume of material composing the beam.

w = weight of unit of length of the uniform load.

P = the concentrated load,

x, y and u co-ordinates of length, depth and breadth of beam respectively.

$\frac{1}{6}Ruy^2$ = moment of ultimate resistance of beam of rectangular sections, where y = depth.

$\frac{1}{4}Ry^3$ = similar moment for beam of circular sections where y = radius.

As a first example, suppose the

BEAM FIXED AT ONE END AND FREE AT THE OTHER,

the weight of beam, and weight P at free end, being the loading.

With the exception of the moment of P, the equation of moments for this beam is given in Professor Wood's book, 2d edition, p. 193, so that by adding the moment of P, simply Px, gives us

$$Px+\delta d\int u\,dx\left(x-\frac{\int xu\,dx}{\int u\,dx}\right)=\frac{1}{6}Rud^2 \quad (1)$$

which supposes the origin of co-ordinates to be taken at the free end of the beam.

The relation of u and x, required for performing the integrations indicated, is involved in the expression itself, and hence it will be necessary to remove the integral signs by differentiating.

Differentiating twice, cancelling common terms and reducing, we obtain

$$u\frac{6\,d}{Rd}=\frac{d^2u}{dx^2}\cdot=\frac{u}{m} \quad \text{if} \quad m=\frac{Rd}{6\,d}.$$

Multiplying through by du and integrating, we obtain

$$\frac{du^2}{dx^2}=\frac{u^2}{m}+C=\frac{1}{m}(Cm+u^2) \quad . \quad (2)$$

Extracting the square root, solving for dx, multiplying by u, and integrating between limits o and contemporaneous values of x and u, we get

$$\int_o^x u\,dx=\sqrt{m}\int_o^u\frac{u\,du}{\sqrt{Cm+u^2}}$$
$$=\sqrt{m}\,(\sqrt{Cm+u^2}-\sqrt{Cm}) \cdot \quad (3)$$

Substituting this for the same expression found in the first differential of equation (1), and we get

$$P dx + \delta d\, dx \sqrt{m}\,(\sqrt{Cm+u^2} - \sqrt{Cm})$$
$$= \frac{R d^2}{6} du, = \delta dm du, = \delta d \sqrt{m} \sqrt{Cm+u^2}\, dx;$$

The last step requiring (2). Hence,

$$P = \delta dm \sqrt{C}.$$

Substituting C in (2), and reducing, we get

$$x = \sqrt{m} \int_o^u \frac{du}{\sqrt{\frac{P^2}{\delta^2 d^2 m} + u^2}}$$
$$= \sqrt{\frac{R d}{6 \delta}}\ \text{hyp. log.} \left(\frac{u}{P} \sqrt{\frac{R \delta d^2}{6}} + \sqrt{1 + \frac{u^2}{P^2} \cdot \frac{R \delta d^2}{6}} \right) \quad . \quad (4)$$

This is the equation of longitudinal horizontal section of the beam.

Without discussing these equations further at present, we observe that the manner in which C disappeared, and P reappeared after once disappearing, before being required to integrate for x, suggests that a general solution may be effected covering all cases.

To obtain a general solution let k represent the cross section of beam, always considered rectangular. Then $k = uy$, a variable which admits of any assigned relation of u and y. An equation of moments established similarly as was eq. (1), gives

$$\frac{1}{6} R k y = P x + \frac{w x^2}{2} + \delta \int k dx \left(x - \frac{\int x k dx}{\int k dx} \right) \quad (6)$$

in which the first member is equivalent to $\frac{1}{6} R u y^3$, the well known expression, for the moment of ultimate resistance of a beam to transverse forces at a point where the breadth and depth is u and y. The second member is the applied moment, with the origin of moments at the section of beam considered, while the origin of co-ordinates is at the free end of beam. Hence Px is the moment of the force P applied at the free end; wx the uniform load over x, and $\frac{wx^2}{2}$ its moment, since the arm is $\frac{x}{2}$; and $\delta \int k dx$ the weight of beam from o to x; with the expression in the brackets its lever arm, found by subtracting from x, the abscissa of the center of gravity of that part of beam between o and x.

Differentiating once, we obtain

$$\frac{R}{6} \cdot \frac{d(ky)}{dx} = P + wx + \delta \int k dx \quad . \quad (7)$$

which is the shearing stress at any point of the beam, and thus given, according to k; in terms of the tangent, subnormal, or rectangle of y and the subnormal of the curve of the beam. At the free end of beam x and $k = o$ and

$$\frac{R}{6} \cdot \frac{d(ky)_1}{dx_1} = P \quad . \quad . \quad . \quad . \quad (8)$$

Differentiating again, and (7) becomes

$$\frac{R}{6} \cdot \frac{d^2(ky)}{dx^2} = w + \delta k \quad . \quad . \quad . \quad . \quad (9)$$

Multiplying by $d(ky)$ and integrating

$$\frac{R}{12} \cdot \frac{d(ky)^2}{dx^2} = wky + \delta \int_o^{ky} k d(ky) + C. \quad (10)$$

At the free end of beam $k = o$, and, using equation (8)

$$\frac{R}{12} \frac{d(ky)_1^2}{dx_1^2} = C = \frac{3P^2}{R} \quad . \quad (11)$$

Hence, eq. (10),

$$\frac{d(ky)}{dx} = \sqrt{\frac{12}{R}} \sqrt{\frac{3P^2}{R} + wky + \delta \int_o^{ky} k d(ky)} \quad (12)$$

so that the tangent subnormal, etc., are always easily found.

Solving for x, we have

$$x = \sqrt{\frac{R}{12}} \int \frac{d(ky)}{\sqrt{\frac{3P^2}{R} + wky + \delta \int_o^{ky} k d(ky)}} + C' \quad . \quad (13)$$

This solution covers a great number of practical examples, twelve of which follow from supposing depth constant, breadth constant, or depth divided by breadth constant, while the loading may be all present, P absent w absent, or w and P absent. The form of beam for some of these examples will be given below. This equation is not always integrable.

But before proceeding to examples let us examine, in a general way, the case of a

BEAM SUPPORTED AT BOTH ENDS,

the loading being the weight of the beam itself. A concentrated load of 2P at the middle, and a uniform load of w per unit over the whole length. The reac-

tion of each support we may call V,= half the total weight of beam and load.

$$\therefore \quad V=P+wx_2+\delta\int_0^{x_2} kdx \quad . \quad (14)$$

where the subscripts, 2, refer to values for the middle point of beam, the origin of co-ordinates being taken at the end.

The equation of moments, established similarly as before, will be

$$\frac{1}{6}Rky=Vx-\frac{wx^2}{2}-\delta\int kdx\left(x-\frac{\int xkdx}{\int kdx}\right) \quad (15)$$

the moment of all the forces acting on beam at one side only of section considered being taken.

Differentiating once gives

$$\frac{R}{6}\cdot\frac{d(ky)}{dx}=V-wx-\delta\int kdx \quad (16)$$

and for the middle point of beam,

$$\frac{R}{6}\cdot\frac{d(ky)_2}{dx_2}=V-wx_2-\delta\int_0^{x_2} kdx=P, \quad . \quad (17)$$

by eliminating V by aid of (14)

Differentiating again, and (16) becomes

$$\frac{R}{6}\cdot\frac{d^2(ky)}{dx^2}=-w-dk \quad . \quad . \quad . \quad (18)$$

Multiplying by $d(ky)$ and integrating

$$\frac{R}{12}\cdot\frac{d(ky)^2}{dx^2}=-wky-\delta\int_0^{(ky)} kd(ky)+C \quad (19)$$

At middle of beam (19) and (17) give

$$\frac{R}{12}\cdot\frac{d(ky)_2^2}{dx_2^2}=-w(ky)_2-\delta\int_0^{(ky)_2} kd(ky)+C=\frac{3P^2}{R}$$

whence

$$C=\frac{3P}{R}+w(ky)_2+\delta\int_0^{(ky)_2} kd(ky) \quad . \quad . \quad . \quad (20)$$

Eq. (19) gives

$$\frac{d(ky)}{dx}=\sqrt{\frac{12}{R}}\sqrt{C-wky-\delta\int_0^{(ky)} kd(ky)} \quad (21)$$

which gives the tangent subnormal, etc., similarly as before, always obtainable.

Also, solving for x, we have

$$x=\sqrt{\frac{R}{12}}\int\frac{d(ky)}{\sqrt{C-wky-\delta\int_0^{(ky)} kd(ky)}} \quad (22)$$

an equation which is integrable for many practical cases, but not always, as will be seen below.

The present article will be confined to the above two modes of holding or supporting the beam, and we will now pass to practical examples, first considering the

BEAM FIXED AT ONE END.

Case I. Let the depth be constant.

1st. Let all the loading be present. We have

$$k=ud,\ ky=ud^2,\ d(ky)=d^2du$$

and $$\int_0^{ky} kd(ky)=d^3\int_0^u udu=d^3\frac{u^2}{2}$$

These values in (13) give, observing that for $u=o, x=o$,

$$x=\sqrt{\frac{R}{12}}\int\frac{d^2\,du}{\sqrt{\frac{3P^2}{R}+wud^2+\delta d^3\frac{u^2}{2}}}$$

$$=\sqrt{\frac{Rd}{6\delta}}\text{ hyp. log.}\left\{\frac{\delta ud+w+\sqrt{\frac{6\delta}{Rd}P^2+2wu\delta d+w^2\delta^2d^2}}{w+P\sqrt{\frac{6\delta}{Rd}}}\right\} \quad (23)$$

which is the equation of the curve of horizontal section.

When $u=b, x=l$, and the resulting expression shows that the length of beam is dependent upon other quantities, such as depth, breadth, density, etc., or these upon the length. For the tangent, we have from (12),

$$\frac{du}{dx}=\text{tang. } i=\frac{1}{d^2}\sqrt{\frac{12}{R}}\sqrt{\frac{3P^2}{R}+wud^2+\frac{\delta u^2d^3}{2}} \quad . \quad . \quad (24)$$

At the free end,

$$\text{tang. } i_1=\frac{6P}{Rd^2},$$

And at fixed end,

$$\text{tang. } i_2=\frac{6P}{Rd^2}\sqrt{1+\frac{Rwud^2}{3P^2}+\frac{R\delta u^2d^3}{6P^2}},$$

which shows that the tangent line makes the greatest angle with the beam at the fixed end, and hence the sides of the beam are concave.

To find whether the curve has asymptotes place (24)=o, whence

$$\delta ud=-w\pm\sqrt{w^2-\frac{6\delta P^2}{Rd}} \quad . \quad . \quad (25)$$

Placing thus in (23), we find only the plus sign before the radical to be admissible, and by reduction

$$x'=\sqrt{\frac{R\,d}{6\,\delta}}\ \text{hyp. log.}\ \sqrt{\frac{w-P\sqrt{\frac{6\,\delta}{R\,d}}}{w+P\sqrt{\frac{6\,\delta}{R\,d}}}} \qquad (26)$$

the abscissa to the point of the curve where the tangent is parallel to x, and is $-\infty$, or, since u is finite, the curve has an asymptote whenever $w=P\sqrt{\frac{6\,\delta}{R\,d}}$, when $w<P\sqrt{\frac{6\,\delta}{R\,d}}$, there is no asymptote nor parallel tangent; but when $w>P\sqrt{\frac{6\,\delta}{R\,d}}$, the tangent is parallel at a finite negative distance, and for $P=o$, the tangent is parallel at the origin.

Equation (25) gives the value of u for locating the asymptotes, being always negative except when w and P are zero, in which u is zero, or the axis X an asymptote.

Fig. 1 gives a pictorial representation of the beam with its asymptotes. The

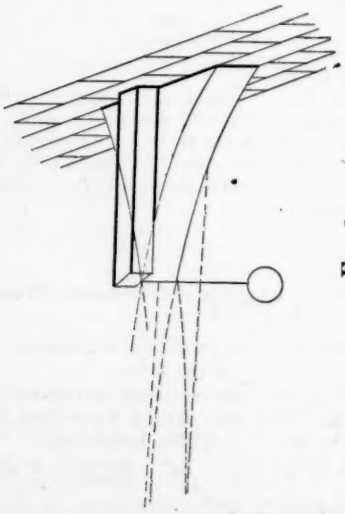


Fig. 1.

curve and beam may extend to infinity in the positive direction of x, where its tangent is perpendicular to X.

2d. Let $w=o$. Then

$$x=\sqrt{\frac{R\,d}{6\,\delta}}\ \text{hyp. log.}\left(\frac{u}{P}\sqrt{\frac{R\delta d^2}{6}}+\sqrt{1+\frac{u^2}{P^2}\cdot\frac{R\delta d^3}{6}}\right) \qquad (27)$$

The same as equation (4) obtained by itself. Also,

$$\text{tang. } i=\frac{6\,P}{R\,d^2}\sqrt{1+\frac{R\delta u^2 d^3}{6P^2}} \qquad (28)$$

and the beam is concave on its sides but less so than in Fig. 1, for eq. (23), the sides meeting at the end with the same angle as in Fig. 1.

As (27) admits of no negative values of x, for u positive or negative, the curve must always end at the point of the beam, and there are no asymptotes.

The beam may be extended in the positive direction to infinity where the tangent line is perpendicular to X, and hence the beam is similar in form to Fig. 1, differing by being more slender and longer for a given breadth.

3d. Let $P=o$ but w present.

We easily obtain from (23) and (24) the characteristics of the beam. It is concave on its sides, may extend to infinity in the positive direction where the tangent line is perpendicular to X, and is cusped at the free end.

3d. Let both w and $P=o$.

This is the same case as considered in Professor Wood's *Materials*, Page 193, under "b", where the constants are left undetermined. The reason for these giving the expression the negative sign does not appear.

Equation next preceeding (23), for w and $P=o$, and for $u=1$ when $x=o$, gives

$$x=\sqrt{\frac{R\,d}{6\,\delta}}\ \log.\ u$$

Either this, or (24), gives

$$u\ \text{cot. } i=\sqrt{\frac{R\,d}{6\,\delta}},$$

which indicates that the subtangent to this curve has a constant value, and equals the radical in the above equations.

As the subnormal is constant in the common parabola it follows that this curve cuts normally all con-axial parabolas distributed along X, whose para-

meters are $P=\sqrt{\frac{Rd}{6\delta}}$. This property enables us to readily draw the outline of the beam.

The beam is therefore concave on its sides, and resembles Fig. 1, except that it extends to infinity, X being an asymptote as previously pointed out.

Case II. Let the breadth be constant.

Then $k=by$, $ky=by^2$, $d(ky)=2bydy$

$$\int_0^{ky} kd(ky)=\tfrac{2}{3}b^2y^3$$

Ist equation (13) becomes

$$x=\sqrt{\frac{R}{12}}\int\frac{2bydy}{\sqrt{\frac{3P^2}{R}+wby^2+\tfrac{2}{3}\delta b^2y^3}} \quad . \quad (29)$$

an expression only integrable in form of a series, except when P or δ are zero; and hence, the curve is not of known form.

Equation (12) reduces to

$$\frac{dy}{dx}=\text{tang. } i=\frac{1}{2by}\sqrt{\frac{12}{R}}\sqrt{\frac{3P^2}{R}+wby^2+\tfrac{2}{3}\delta b^2y^3} \quad . \quad (30)$$

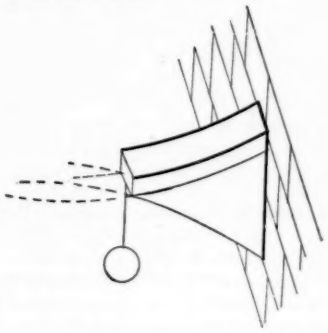
When $y=o$ tang. $i=\infty$, and hence the beam is rounded at the end. Multiplying through by y, and we obtain an expression for the subnormal, which is found to increase in some manner with y. In the parabola the subnormal is constant, while in the straight line it is proportional to y. Hence the curve lies between a parabola and straight line, of some values of l and d, and resembles the former.

2d. Let $w=o$. We are still unable to find x in convenient terms; but the subnormal increases with y, though less rapidly than before, and hence the curve lies between the previous one and the parabola.

3d. Let $P=o$, but w present. Then (29) reduces to

$$x=\sqrt{\frac{2R}{\delta}}\left(\sqrt{\frac{3w}{2\delta b}}+y=\sqrt{\frac{3w}{2\delta b}}\right), \quad . \quad (31)$$

the equation of a parabola whose parameter, p, is $\frac{R}{\delta}$; and with principal axis perpendicular to X. The vertex is at a point whose co-ordinates are $-\sqrt{\frac{3Rw}{\delta^2 b}}$ and $-\frac{3w}{2\delta b}$ for X and Y respectively, and the form of the beam is shown in the Figure. FIG. 2.



4th. Let w and $P=o$. Eq. (31) then reduces to

$$x^2=\frac{2R}{\delta}y \quad . \quad . \quad . \quad . \quad (32)$$

a parabola, and the same equation and figure as given for this case in Professor Wood's *Materials*, p. 193.

Case III. Let the cross sections of beam be rectangular and similar. For this, (13) is never integrable in finite terms except when w and P are zero, and then

$$x^2=\frac{5R}{\delta}y \quad . \quad . \quad . \quad (33)$$

a parabola.

As the relation of the moment of resistance of beams of rectangular and circular sections are as 1 to $\frac{5}{8}$, the depth in the former being equal to radius in latter, equation (33) becomes, for circular sections

$$x^2=\frac{15}{2}\frac{R}{\delta}y$$

the same as given for this case in Wood's *Materials*, p. 194.

NEXT LET THE BEAM BE SUPPORTED AT BOTH ENDS.

Case IV. Let the depth be constant.

1st. Take the loading w per foot, 2 P at the middle, and the beam itself

$k=ud$ $ky=ud^2$ $d(ky)=d^2\,du$

$$\int kd(ky)=d^2\frac{u^2}{2}.$$

These introduced in equation (22), observing that for $x=ou=o$, reduce it to

$$x=\sqrt{\frac{\overline{\mathrm{R}d}}{6\delta}}\left(\text{arc. sin.}\ \frac{\delta u d^2+wd}{\sqrt{2\mathrm{C}\delta d+w^2d^2}}-\text{arc. sin.}\ \frac{w\,d}{\sqrt{2\mathrm{C}\delta d+w^2d^2}}\right). \quad (34)$$

in which

$$\mathrm{C}=\frac{3\mathrm{P}^2}{\mathrm{R}}+wbd^2+\frac{\delta d^2b^2}{2},$$

b and d being the breadth and depth at middle of beam.

It may be remarked that the negative signs under the radical require for this a different formula for integration than that used for Case I, though the exponents are the same. See *Redtenbacher Resultats* 2d. French Ed. p. 492.

The curve is that of a sinusoid, more or less elongated or stretched out in the direction of the axis, according to the coefficient $\sqrt{\frac{\overline{\mathrm{R}d}}{6\delta}}$.

The point of deflection is to be found where

$$\frac{d^2u}{dx^2}=o.$$

This, see equation (18) gives

$$u=-\frac{w}{\delta d}$$

for the ordinate of the point. This in (34) makes the first term in the brackets zero and gives a negative value for the abscissa X. Thus the position of the point of inflection becomes known, and is in a negative direction on both axes.

Again if we make tang. $i=o$ we find x greater than $\frac{l}{2}$, so that the sides meet at an angle in the middle, and the form of beam is shown in Fig. 3, in horizontal projection.

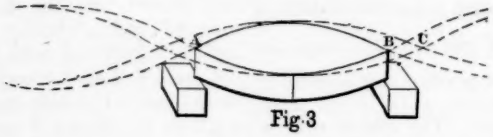


Fig. 3

2d. Let $w=o$. Then

$$x=\sqrt{\frac{\overline{\mathrm{R}d}}{6\delta}}\ \text{arc. sin.}\ \frac{u}{\sqrt{\frac{6\ \mathrm{P}^2}{\mathrm{R}\delta d^2}+b^2}}$$

an extended sinusoid, with the point of inflection at the origin.

By means of the equation for tang. i, we find that the sides of the beam meet at the middle with the same angle as before, while at the end the angle of junction is less than before, and the form of beam though more slender, is similar to Fig. 3, A and B being points of inflection in the curves.

3d. If $\mathrm{P}=o$ and w present the side of beam will consist of one continuous sinusoid, with position of point of inflection negative on both axes.

4th. Let P and W $=o$, the beam being the only load. Then

$$x=\sqrt{\frac{\overline{\mathrm{R}d}}{6\delta}}\ \text{arc. sin.}\ \frac{u}{b},$$

and tang. $i=\sqrt{\frac{6\delta}{\overline{\mathrm{R}d}}}\sqrt{b^2-u^2}$.

Hence the beam is an elongated sinusoid with continuous sides, and the point of inflection at the origin, one side of beam taking just the whole branch of curve.

Observing that $x=\frac{l}{2}$ for $u=b$ we find

$$l=\pi\sqrt{\frac{\overline{\mathrm{R}d}}{6\delta}}.$$

The form of beam is shown in Fig. 4.

Case V. Let the breadth be constant. Then

$$x=\sqrt{\frac{\overline{\mathrm{R}}}{12}}\int\frac{2bydy}{\sqrt{\mathrm{C}-wby^2-\frac{3}{4}\delta b^3y^2}} \quad . \quad . \quad (35)$$

only integrable for $\delta=o$, observing that $c=o$ requires $\delta=o$, and hence the curves are not of known form.

If, for instance, δ and $\mathrm{P}=o$, the equation reduces to

$$x=\sqrt{\frac{\overline{\mathrm{R}b}}{3w}}(d-\sqrt{d^2-y^2})$$

which, by observing that for $y=d, x=\frac{l}{2}$, reduces to

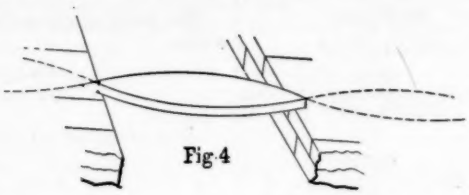


Fig. 4

$$\frac{w}{2}(lx-x^2)=\frac{R}{6}by^2,$$

an ellipse, and the same equation as given for this example in Wood's *Materials*, p. 195.

To gain some knowledge of the form of the beam for equation (35), we obtain, for the subnormal

$$y\frac{dy}{dx}=\frac{\sqrt{3}}{\sqrt{Rb^2}}\sqrt{\frac{3P^2}{R}+wb(d^2-y^2)+\tfrac{2}{3}\delta b^2(d^3-y^3)} \quad (36)$$

The maximum for this is for $y=o$, or for the end of beam. At the middle it is $\frac{3P}{Rb}$. In the ellipse the subnormal decreases in value from the end, to zero at middle of major axis, while in the parabola it is constant. The above subnormal at middle of beam is usually very small and between those of the two conics named, but at the end we are not able thus to compare. A beam without weight, with load w, only we have seen is elliptical, while with load P, only at middle, it is known to be parabolic.

By making the beam itself part of load, the greatest intensity of this will be at middle, though extended throughout. This tends to place the form of beam between the two conics, whether P, or w, or both, are present.

It would appear therefore that the form of beam, equation (35), lies between the parabola and ellipse, being nearest elliptical when P is absent, and nearest to parabola when w is absent. Equation (36) shows that the beam always has rounded ends, whether any one or all the three forms of load are present.

Case VI. Let the sections be similar rectangles. For this, eq. (22) is not integrable except for $\delta=o$.

The desired curves, therefore, cannot be classified, though some knowledge of them may be obtained by interpretation, similarly as in the last example above.

THE SUPPLY OF AIR TO FURNACES.

From "The Engineer."

To effect the complete combustion of one pound of good Welsh coal 12 lbs. of air are sufficient in theory. That is to say, 12 lbs. of air contain sufficient oxygen to effect the complete combustion of 1 lb. of coal. In practice, however, a much greater quantity of air than this is necessary, because it is impossible to bring all the oxygen in 12 lbs. of air into intimate contact with a pound of burning fuel, and it is usually estimated that from 18 lbs. to 24 lbs. are actually required in practice. It is to be regretted that very few experiments have been made to test this point practically. Such data as we do possess, however, go to confirm the accuracy of the preceding figures. It is well known that the admission of too much air to a furnace reduces the production of steam, and is otherwise uneconomical; but we have reason for stating that it is not generally known why it is prejudicial to admit too much air. When a fire-door is opened the draught is spoiled for the time, and the production of steam is lessened because the quantity of coal burned in any given time is reduced. But besides this, in popular language the flues and boiler are said to be cooled down by the influx of air which has not been raised in temperature by passing through the fire-

bars. All this is well enough and sound enough as far as it goes; but it does not go nearly far enough, and we propose here to explain very briefly one aspect of the case which is continually overlooked. Every steam boiler with its furnace is not only a water heating apparatus, but an air heating apparatus as well, and the more heat we expend in raising the temperature of air the less we shall have for the generation of steam. The exact proportions of the heat given out by the combustion of a pound of coal, which goes to the water and is wasted in raising the temperature of air, admits of precise determination. A pound of good coal will, during its perfect combustion, give off 14,500 units of heat—that is to say, as much heat as would raise 1 lb. of water 14,500 deg., or 14,500 lbs. of water 1 deg. In some cases coal gives out more heat than this because of the hydrogen which it contains, in some cases less; 14,500 may be taken as a fair mean. Now, a pound of steam at 75 lbs. absolute pressure contains 1,176 units of heat—that is to say, if we take 1 lb. of water at 32 deg. and boil it and evaporate it under an absolute pressure of 75 lbs. on the square inch, we must expend 1,176 units of heat. As a pound of coal gives out 14,500 units, it follows that a pound of coal can convert into steam $\frac{14,500}{1,176} = 12.33$ lbs., and this is the maximum possible evaporation under the conditions. Of course, if the feed-water is heated the evaporation will be greater. Thus, if the fuel reached a temperature of 212 deg., then the number of additional units of heat required to convert a pound of water into steam would be only 996 instead of 1,176, and $\frac{14,500}{996} = 14.55$ lbs. as the maximum possible evaporation. When we hear of boilers which evaporate 15 lbs. and 16 lbs. of water per pound of coal, we know that the statements made concerning them are simply untrue. But it is not so generally understood that an evaporation of anything like even 14 lbs. is almost impossible of attainment, for the reason which we have already given—namely, that the furnace is an air heater as well as a water heater.

Let us for the moment suppose that a boiler is so well clothed that the loss of heat by radiation may be neglected, and the temperature of the escaping products of combustion, *as they leave the boiler*, is 500 deg. It is not easy to get them less than this with 75 lbs. steam, the sensible temperature of which is 307 deg. Let the consumption of air be the lowest possible—say 20 lbs. per pound of coal burned. The specific heat of air is .238, that of water being 1. That is to say, to heat a pound of air through a certain number of degrees will require only .238 times as much heat as would be needed to raise a pound of water through the same number of degrees. Let us suppose that the temperature of our 20 lbs. of air is 50 deg. In the furnace it will probably be raised to 2,000 deg. or 2,500 deg.; but with this we have nothing to do, because in the flues it gives up, to a considerable extent, to the water in the boiler the heat it received in the furnace. What we have to deal with are the temperatures of the air going into the furnace and leaving the flue. These we have assumed to be 50 deg. and 500 deg. respectively, consequently our 20 lbs. of air has been raised through 450 deg., and to effect this 20×450 deg. $\times .238 = 2,142$ units of heat must be expended; and as these are carried up the chimney they are totally lost. But 2,142 units would suffice for the evaporation of 2.15 of water, the feed being heated to 212 deg., and this must be deducted from the rate of evaporation, based on the assumption that nothing is wasted up the chimney. Consequently $14.56 - 2.15 = 12.41$ lbs. may be taken as the maximum possible evaporation to be had under the conditions. There are certain boilers in use, however, in which the heat of the escaping products of combustion is not more than 50 deg. greater than that of the steam; and with such boilers, and with some of the Welsh coals which contain as much as 15,300 heat units per 1 lb., an evaporation of 12.5 lbs. of water may be reached in practice. Results apparently greater than this have been attained, but they must be attributed either to priming which raised the consumption of feed-water; or to the use of feed-water heated to a temperature even greater than that in the boiler, as not unfrequently happens when good "econo-

mizers" are used. We have said enough, we think, to show that it is highly desirable that the consumption of air per pound of fuel should be made as small as possible.

If any apology were needed for placing before our readers a statement of truths with which every engineer should be familiar, it would be found in the circumstance that we have recently received a circular which is now being issued by the inventor and patentee of a well-known, and we may add excellent, fire-door, intended to prevent the production of smoke. This circular sets forth particulars of a trial conducted at Messrs. Hanley's Telegraph Works, with two Lancashire boilers, one fitted with the fire doors, to which we have just referred, the other having ordinary doors. The trials seem to have been carefully conducted, with the result that the boiler with the patent door evaporated 11.44 lbs. of water per pound of coal, while the ordinary boiler evaporated but 9 lbs. We would pass this statement over in silence, because it does not contain any strong improbability, although we doubt that any fire-door or smoke consuming appliances in existence possesses so much merit. But we cannot pass over what follows. It appears that to make the data complete, the author of the circular under notice used a patent anemometer to measure the quantity of air admitted to the furnace, by which it was ascertained that with the patent fire-doors 491.4 cubic feet of air were used per pound of coal, while the ordinary boiler used 196.6 cubic feet only. Taking the temperature of the air in the boiler room as between 60 deg. and 70 deg., we shall not be far wrong if we assume that 14 cubic feet of air weighed 1 lb. Thus the consumption of air with the patent door was $\frac{491.4}{14} = 35.1$ lbs. per lb. of coal. The temperature of the products of combustion leaving the flues is not stated, but it could not have been much under 600 deg., judging from our experience of Lancashire boilers. We shall be on the safe side if we estimate that each pound of the 35 lbs. of air admitted to the furnace carried away 500 heat units with it. Then $35 \times 500 \times .238 = 4{,}165$ as the total loss of heat, but $\frac{4{,}165}{996} = 4.18$ lbs. of water if the feed had been heated to 212 deg. As this is improbable, however, we shall say that enough heat went up the chimney per lb. of coal burned to evaporate 3.75 lbs. of water. Now, we are told that the actual evaporation was 11.44 lbs. Adding to this the 3.75 lbs., we have as the total heat in each pound of coal enough to evaporate 15.19 lbs. of water from 100 deg. to 50 lbs. or 60 lbs. steam, and this without leaving anything for loss by radiation or conduction. We have just endeavored to show that such a result is physically impossible of attainment. It remains for the gentleman who has issued the circular to the confiding steam users of the kingdom to explain the inconsistency. Either his anemometer deceives him, or his feed-water measuring arrangements were at fault.

Turning to the boiler without the patent fire-door, we find it stated that while the evaporation was 9 lbs. of water per pound of coal, the consumption of air was 198.6 cubic feet, or, in round numbers, 14 lbs. per pound of coal. It is barely possible that complete combustion could be effected with so small an admission of air; and the probability is that the boiler smoked a good deal. But the quantity of heat carried off in the air could not have exceeded 1,666 units per pound of coal, or say the equivalent of 1.5 lbs. of water evaporated. If we add this to 9 lbs. we have 10.5 as the value of the coal, and allowing for loss by radiation, it would appear that this boiler was not worked to much disadvantage. It would probably have done better with more air. But, as we have shown, an admission of 35 lbs. per pound of coal would have represented the absolute loss of 3.75 lbs. of steam per pound of coal; that is to say, before any advantage could be gained from the extra admission of air the coal must give out per pound, heat equivalent to 9 lbs. + 3.75 lbs. of water converted into steam; but, inasmuch as the coal could not do this, we fail to see how any advantage could possibly be gained.

The lesson taught by the circular we have criticised is that a great deal has yet to be learned by men who undertake to improve the performance of steam

machinery. As we have said already, we believe that the fire-door concerning which the circular has been issued is a very good and simple appliance; and we feel perfectly certain that the writer of the circular had no intention of deceiving the public. If he had been better informed, he would have stopped to think how such and such things could be before he rushed into print. As the matter stands, we can hardly sufficiently admire the exquisite *naiveté* of an inventor who can boast that he uses more air per pound of coal than other men. There is reason to believe that he does not yet understand that the real merit of his invention lies in its great simplicity, and the efficiency with which it supplies a portion of the air requisite for combustion exactly in the right place and in the right way. If he works his apparatus in such a fashion that he admits 35 lbs. of air per pound of coal, then he is doing his invention a grave injustice, and proving very clearly that, whatever else he may be, he is not a competent stoker.

ON THE CURRENTS IN NAVIGABLE RIVERS.

By A. RULLIER.

From "Revue Maritime et Coloniale."

Rivers in their flow tend to wash the materials of their banks into the bed of the stream. When the current is gentle, the silt and clay in the banks are deposited in the center, and the sandy portions at the sides; the bed of the river is gradually raised, and the width increased. When the current is rapid the banks are undermined, the lighter particles are carried away, and the heavier portions remain at the sides impeding the undermining action, and the bed of the river is deepened: this action continues till the current slackens, when the banks again gradually resume their original slopes. The navigation of the straight reaches of a river presents no difficulty; the greatest depth is in general in the middle, and large vessels always follow the center of the stream, but vessels of small draught when ascending the river hug one of the banks, as the force of the current is less at the sides than in the center. When the river is shoal on one side the current is diverted towards the opposite bank, which assumes a perpendicular face, indicating thereby the existence of a shoal on the farther side. When banks are formed in a river whose course is straight, they usually are found in the center, of an oval shape in plan, and triangular in longitudinal section; their presence, when below water, is manifested by the deviation of the current and by the ripples they give rise to, behind which the water is smooth. Occasionally the channels on either side of the bank are equally suitable for navigation, but more frequently one channel deepens at the expense of the other, and this is indicated by the steepness of the banks of the deeper channel. When the river takes a bend the direction of the current does not at once follow the altered line of the banks, but approaches the concave bank, and brings the greatest velocity and the greatest depth of the river near that bank. The concave bank is gradually encroached upon, and a deposit is formed near the opposite bank, and the river frequently increases in breadth at the bend. On account of the direction the current takes at a bend, vessels ascending the river hug the convex bank, and, when descending, keep near the concave bank. If the bend is very sharp, the stream is directed with considerable impetus against the concave bank, and, washing away the bank and scouring the bed, strikes across the river towards the opposite bank; silting takes place at the convex bank, which becomes pointed and has a gentle slope, whilst the concave bank is vertical. When the course of the stream is a curve of small radius, the river has generally a small breadth in proportion to the amount of its discharge; the strength of the current

merely approaches the concave bank, and banks are rarely formed in the bed of the stream. When the river curves gently and runs through a loose soil it increases in breadth, diminishes in depth, and banks are frequently formed in the middle.

Through narrow passes the depth of a river is usually considerable, and its flow rapid; in these places vessels are always obliged to keep to the center of the river so as to avoid the whirlpools and back currents caused by projections from the banks. A tributary flowing into a straight reach of a river leads to the formation of a bank, where the current of the tributary is checked by impinging upon the main stream, and, other conditions remaining the same, the size of the bank is proportional to the angle of inclination between the two streams. The best channel for vessels is generally on the side where the tributary flows in, except when the latter is very small. When the junction of the tributary occurs at a bend in the river on the concave side, the bed is scoured on that side; and a deposite is formed at the point where the bank and the tributary unite, the convex bank is little affected by the confluence of the two streams. If the mouth of the tributary is on the convex side of a bend in the main river, the tributary, finding little resistance at its mouth, on account of the sluggishness of the river round the convex bank, continues its course for some distance across the main stream till it gradually merges into it, turning the direction of the current, when the tributary is strong, still more against the concave bank and increasing the encroachment on that side. When the main stream takes a sharp bend and the tributary flows in on the concave side, the result is very similar to the case just considered. A tributary flowing in where the river is curving gently, and above the part where banks tend to form, renders the navigation very complicated, as a bar is formed which sometimes extends so as to unite with the banks in the river. The navigable channel is almost always situated close to the mouth of the tributary, gradually tending towards the center of the river.

When the junction occurs where the river is obstructed by banks, the waters of the tributary assist in opening a passage through the banks and improving the navigable channel.

The Author explains at some length the proper measures to be adopted, in river navigation, in casting and weighing anchor, and the course that should be followed by a vessel going up or down a river in the various cases mentioned above.

STEAM INJECTORS.

Translated from the French of M. LEON POCHET.

I.

GENERAL THEORY OF STEAM INJECTORS.

It is some years since M. Giffard introduced the injector apparatus which bears his name and which filled the scientific world with profound astonishment.

This ingenious apparatus, in which a jet of steam heading out of a boiler enters into the same boiler bringing with it a quantity of additional water, seems to proceed in accordance with a philosophical law contradictory to the ordinary laws of physics. It was in appearance a sort of perpetual motion. If the mechanical properties of heat had been better known, nothing would have appeared more simple.

M. Reech, published, in 1858, (in the memorial du Genie Maritime), a theory founded upon laws of the old philosophy, which gives a good account of the functions of the Giffard injector.

The new theory which we proceed to give—of the Giffard injector in particular, and of steam injectors in general—rests upon the mechanical theory of heat. It seems the more important inasmuch as injectors are now applied to such a great variety of purposes.

We will describe first the action of an

injector. A tube terminating in a conical pipe A, Fig. 1 discharges a jet of steam which comes from the boiler. This tube opens into a chamber B B which communicates with a reservoir of cold water RR by a vertical tube CC. It is this water which is introduced into the boiler.

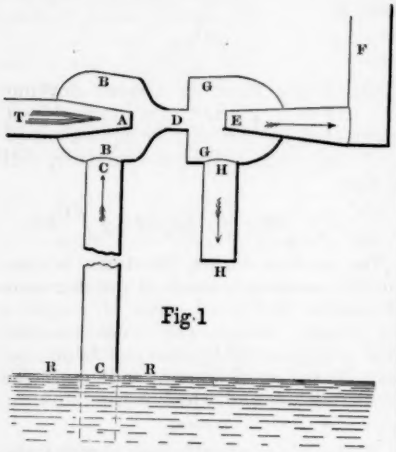


Fig. 1

Under the action of the jet of steam the air in the chamber B is rarefied and the rarefaction results in the atmospheric pressure raising the water of the reservoir in the tube C. As soon as the cold water comes in contact with the steam in the chamber B a portion of the steam is condensed and the apparatus is so regulated that this condensation is complete. Then we have, merely, a jet of liquid to pass on through the contracted section D and be introduced into the conical, diverging tube which communicates with the boiler. The tube EE is nothing more than a Venturi tube.

In such a tube, water introduced with a certain velocity V would be able to overcome the pressure due to the height $\frac{V^2}{2g}$, provided that the liquid column be uninterrupted and the widening be progressive; or if we call ω the section of the tube at its origin, and ω' the section of the same tube at its entrance into the boiler, H the height of water corresponding to the effective pressure of the boiler, that is to say its absolute pressure diminished by one atmosphere, we shall have

$$\frac{V^2}{2g}\left(1-\frac{\omega^2}{\omega'^2}\right)=H.$$

In the Giffard injector we make

$$\frac{\omega}{\omega'}=0{,}16.$$

whence

$$\frac{\omega^2}{\omega'^2}=0{,}0256,$$

consequently

$$\frac{V^2}{2g}\times 0{,}9744=H.$$

But we should be able to give to the ratio $\frac{\omega}{\omega'}$ greater value, and we can always assume approximately :

$$\frac{V^2}{2g}=H.$$

The condition that the liquid jet, through the tube E E, is uninterrupted assumes that the jet is at too low a temperature to be transformed into steam at the atmospheric pressure in its passage through the chamber G G. Hence its temperature should be below 100°.

Should the temperature exceed 100° the working of the apparatus is imperfect. We are warned by a production of steam which fills up the chamber G G and which escapes by the discharge pipe H H.

Then we should remove the pipe A of the contracted orifice D in order to increase the useful section of this orifice, or, we should lessen the quantity of steam of the jet by diminishing the orifice A by the conical rod T. Thus the conditions of the proper working of the apparatus are:

1st. That all of the jet of steam A be condensed by affluent water;

2d. That the temperature of the mixture be lower than the temperature of corresponding saturation at the mean pressure of G.

In case that the chamber G communicates with the atmosphere, the temperature of corresponding saturation is 100°. But it might happen that there be any pressure in the chamber G. It may be higher or lower than the atmospheric pressure. We will make no special hypothesis upon its value.

Call t_0 the temperature of the boiler;

t the temperature of the jet of steam

at the moment that it fills the chamber BB. This temperature will be the temperature of saturation corresponding to the mean pressure. It is easy to see that this pressure equals the atmospheric pressure diminished by the height of the column of water CC, if the feeding reservoir RR is lower, and augmented by this height if it is higher.

τ, the temperature of the liquid jet at the moment that it enters the divergent tube EE. This temperature is lower than 100° when the chamber GG communicates with the atmosphere, which is the case in the Giffard injectors;

θ, the temperature of the water in the reservoir RR.

Suppose one kilogramme of saturated steam issuing from the pipe A and containing a proportion x of steam.

Let y be the weight of water which the kilogramme of steam raises and conveys from the reservoir RR.

Let w be the velocity of the steam jet in A;

V the velocity of the mixture at the entrance of the tube E. To solve the problem we will write two equations.

1st. We assume that since there is no heat lost or gained by the material of the apparatus, the sum of internal heat augmented by the calorific equivalent of the living force has not changed during the phenomena; for this heat should always appear under the form of heat, or under the form of living force. This is in accordance with the theorem of living force developed by the theory of heat.

2d. The theorem of rational mechanics relating to momentum is here applicable as it always is whatever the exchange of heat may be, for in the equation of this theorem the interior forces disappear. The amount of internal heat above 0° in a kilogramme of steam of the jet A is:

$$\int_0^t ldt + (r - \mathrm{A}pu)x.*$$

The calorific equivalent of the living force has for value $\frac{\mathrm{A}w^2}{2g}$.

The total quantity of heat is

$$\frac{\mathrm{A}w^2}{2g} + \int_0^t ldt + (r - \mathrm{A}pu)x.$$

The internal heat of the affluent water is

$$y\int_0^\theta ldt.$$

The living force is almost nothing and may be neglected; the internal heat augmented by the calorific equivalent of the living force before the mixture, will be then

$$\frac{\mathrm{A}w^2}{2g} + \int_0^t ldt + (r - \mathrm{A}pu)x + y\int_0^\theta ldt.$$

The mixture forms, the steam is completely condensed, there is a diminution of volume and production of negative mechanical work. The total internal heat is augmented by the calorific equivalent of the work corresponding to the condensation, and which is

$$\mathrm{A}pux.$$

When the mixture passes through the contracted section D, the sum of the living force and of the internal heat is

$$\frac{\mathrm{A}w^2}{2g} + \int_0^t ldt + rx + y\int_0^\theta ldt \quad . \quad . \quad \text{(A)}.$$

The introduction commences in the tube EE, the total weight of the mixture

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* The internal heat of any humid vapor, that is, part liquid and part vapor, is determined as follows:

Let x=the weight of the vapor in a kilogramme of the mixture.

Then $1-x$ the weight of the water in a kilogramme of the mixture.

Then the excess of internal heat of the vapor at t^0 compared with water at 0° is,

$$(r + \mathrm{L} - \mathrm{A}pu)x.$$

In this expression,

L is the quantity of heat required to raise a kilogramme of the liquid from 0° to t^0 when in contact with its vapor.

A is the reciprocal of the Mechanical Equivalent of heat or $\frac{1}{424}$.

p is the pressure.

r is the latent heat of the vapor,

u is the excess of volume of the vapor over the liquid which yielded it.

pu is therefore our expression for work;

And Apu is its heat equivalent.

Now, as the latnet heat liquid in the vapor is $\mathrm{L}(1-x)$, the total internal heat,

$\mathrm{Q}=\mathrm{L}(1-x)+(r+\mathrm{L}-\mathrm{A}pu)x.$

$=\mathrm{L}+(r-\mathrm{A}pu)x.$

Or if l is the specific heat of the liquid at the temperature t^0, then

$$\mathrm{L}=\int_0^t ldt$$

$$\mathrm{Q}=\int_0^t ldt+(r-\mathrm{A}pu)x.$$

is $(1+y)$, its internal heat, since it is entirely in a liquid state, is expressed by

$$(1+y)\int_0^t ldt,$$

And its living force is,

$$(1+y)\frac{AV^2}{2g},$$

since V is the common velocity.

The sum of internal heat above O, and of the calorific equivalent of the living force at the inlet of the tube EE, is therefore

$$(1+y)\left(\int_0^\tau ldt+\frac{AV^2}{2g}\right)$$

This new expression of the total heat should be equal to the expression in (A). We have the equation

$$\frac{Aw^2}{2g}+\int_0^t ldt+rx+y\int_0^\theta ldt=(1+y)\left(\int_0^\tau ldt+\frac{AV^2}{2g}\right) \quad . \quad . \quad (B)$$

Now in consequence of the fundamental formula for the cooling of vapors, we have

$$\frac{Aw^2}{2g}=\int_t^{t_0} ldt+r_0x_0-rx,*$$

Substituting this value in the preceding equations it gives, after some transformations,

$$\int_\theta^{t_0} ldt+r_0x_0=(1+y)\left(\int_\theta^\tau ldt+\frac{AV^2}{2g}\right) \quad (C)$$

This is the equation of living force. We will now establish the equations of momentum. We shall have them due to the contracted section D,

$$\omega V,$$

for this section is necessarily equal to that of the inlet of the tube EE and the weight of water has for its value

$$1000\omega V.$$

Its mass is

$$\frac{1000\omega V}{g}.$$

In short, the expression for momentum is

$$\frac{1000\omega V}{g}V=\frac{1000\omega V^2}{g}$$

The amount of work of the affluent water from the reservoir RR may be neglected. As for the steam jet A, the amount delivered per second is evidently equal to that of the final mixture divided by $(1+y)$, and its velocity is w and its quantity of work is therefore, before its passage into section D

$$\frac{1000\omega}{g}V-\frac{w}{1+y}.$$

and we find also for the increase of the momentum during a second from one side to the other of the contracted section D

$$\frac{1000\omega}{g}V\left(V-\frac{w}{1+y}\right)$$

Let us call π the pressure per square meter in the chamber GG, which is equal to the atmospheric pressure in the Giffard injectors, and P the pressure in the chamber BB which is equal to the atmospheric pressure diminished or increased by the column of water CC according as the supply reservoir RR is below or above the apparatus.

The contracted section D separates the jet into two parts, that above being subjected to the pressure P, and that below to the pressure π. The impulse of exterior forces during the exchange of velocities will be, per second

$$(P-\pi)\omega,$$

We have then, in accordance with the principle of equality of moments

$$\frac{1000\omega}{g}V\left(V-\frac{w}{1+y}\right)=(P-\pi)\omega,$$

Whence

$$V\left(V-\frac{w}{(1+y)}\right)=\frac{(P-\pi)g}{1000}. \quad . \quad . \quad . \quad (D)$$

The two equations (C) and (D) include the theory of steam injectors.—I copy here:

$$\int_\theta^{t_0} ldt+r_0x_0=(1+y)\left(\int_\theta^\tau ldt+\frac{AV^2}{2g}\right), \quad (C)$$

$$V\left(V-\frac{w}{1+y}\right)=\frac{(P-\pi)g}{1000}. \quad . \quad . \quad . \quad . \quad (D)$$

GIFFARD INJECTORS FOR FEEDING BOILERS.

In the Giffard injector (Fig. 1) the reservoir R R is ordinarily near the chamber B B, the pressure P is nearly equal to the atmospheric pressure, and as the chamber G G is in communication with the atmosphere,—we can take

* r_0 and r designating the quantities of heat of vaporization at the temperatures t_0 and t.

$$P=\pi,$$

and we ought to have

$$\tau<100^{\circ}.$$

Equation (D) of the moments reduces to

$$V-\frac{w}{1+y}=0,$$

whence

$$V=\frac{w}{1+y}.$$

Take now the equation (C). In the second member of that equation we may neglect the term $\frac{AV^2}{2g}$

In effect the range of temperature τ and θ is always large enough. The following table demonstrates that V varies almost precisely as the difference $(\tau-\theta)$:

The equation (C) gives then approximately,

$$1+y=\frac{\int_{\theta}^{t_0} ldt+r_0x_0-\theta}{\tau-\theta} \quad . \quad (E)$$

Under this form we observe that y diminishes as τ increases. The minimum of y corresponds then with the maximum of τ, that is to say, at 100°.

We see also that y increases when θ increases; that is to say, in proportion to the heat of the feed water.

y increases in the same proportion that the temperatures τ and θ approach each other in value. Consequently when $\theta=100^{\circ}$ y is infinite.

Experience demonstrates that the action of the injector ceases before reaching this limit, at about 70°.

WEIGHT OF WATER RAISED AND VELOCITY OF MIXTURE IN GIFFARD INJECTOR FOR FEEDING BOILERS.

Value of θ	Temperature of the Mixture.	Pressure of the Boiler. 5 Atmospheres. (152°,22), w=714m. Weight of Water raised per kilogr'm of steam suppos'd to be dry y	Velocity of the Mixture per second. V	Height to which the jet is raised. $\frac{V^2}{2g}$	Mechanical Work produced. $y\frac{V^2}{2g}$	3 Atmospheres. (133°,91), w=596m. Weight of Water raised per kilogr'm of steam suppos'd to be dry y	Velocity of the Mixture per second. V	Height to which the jet is raised. $\frac{V^2}{2g}$	Mechanical Work produced. $y\frac{V^2}{2g}$
		k.	m.	m.	km.	k.	m.	m.	km.
	100	6,35	97,29	482,3	3063	6,29	81,73	340,5	2141
	80	8,55	74,87	285,7	2443	8,47	62,94	201,9	1710
θ=13°	60	12,61	52,54	140,7	1774	12,50	44,15	99,4	1242
	40	22,70	30,17	46,4	1053	22,50	25,36	32,8	737
	20	90,42	7,82	3,12	282	89,63	6,57	2,21	197
	13	∞	0	0	0	∞	0	0	0
	100	11,06	59,29	179,2	1981	10,95	49,88	126,8	1389
θ=50°	80	19,10	35,57	64,5	1232	18,92	29,95	45,6	864
	60	59,50	11,85	7,17	425	58,74	9,97	5,07	298
	50	∞	0	0	0	∞	0	0	0

We are able then to state the following propositions.

1st. The proportion of conveyed water increases and, consequently, the velocity of the mixture diminishes when the temperature of the water in the supply reservoir is raised.

2d. The proportion of conveyed water increases when the temperature of the mixture dimimishes. It is a minimum

when the temperature of the mixture is of 100°. The velocity then attains its maximum.

3d. It diminishes, on the contrary, when the steam is not dry and the proportion of water which it contains increses.

In preceeding page is a table of the values of y and of V for the boiler pressures of five and three atmospheres and the temperatures of 13° and 50° of the feeding water, the steam being dry.

The proportion of water raised increases rapidly as the temperature τ of the mixture diminishes.

The velocity diminishes in nearly the same ratio.

The quantity of water raised corresponding to the boiler pressures five atmospheres and three atmospheres are nearly the same, but the velocities are widely different. If we would have the velocity, and, consequently, the composition of the mixture corresponding to the pressure of the boiler, we must make

$$\frac{V^2}{2g} = \begin{matrix} 41{,}32 \text{ for five atmospheres,} \\ 20{,}66 \text{ for three atmospheres,} \end{matrix}$$

whence

$$V = \begin{matrix} 28^m{,}50 \text{ for five atmospheres,} \\ 20^m{,}15 \text{ for three atmospheres.} \end{matrix}$$

These numbers correspond to

$$y = \begin{matrix} 24{,}06 \text{ for five atmospheres,} \\ 31{,}02 \text{ for three atmospheres.} \end{matrix}$$

The temperature of the mixture is nearly 40° if the temperature of the feed-water is 13°.

ACTION OF THE GIFFARD INJECTOR.

There are two ways of considering the action of the Giffard injector. We measure the mechanical work performed without taking into account the heat carried away by the mixture; or, with taking this heat into account.

Following the last mode of operation, which is the only rational one, when employed in feeding the boiler the injector performs good service. It is clear that, since there is no loss of heat outside, and that the final living force is nothing, all the heat carried away by the steam jet is restored in the mixture, excepting that corresponding to the mechanical work accomplished, $\frac{AV^2}{2g}y$. Equation (C) is the mathematical expression of this fact.

It is not necessary to take into account the friction in the tubes, if we consider them impervious to heat, for the friction produces heat which is not lost by external radiation, but is found in the internal heat of the mixture.

The quantity of heat augmented by the living force in the mixture at the moment of its entrance into the convergent tube counted above, the temperature θ (which is the exterior temperature, and which serves as the starting point for the temperature in the equation (C)) is

$$(1+y)\left(\int_o^\tau l dt + \frac{AV^2}{2g}\right).$$

The portion $(1+y)\frac{AV^2}{2g}$ represents the heat equivalent of the living force of the mixture. This living force in part disappears in the work of introduction into the boiler. If things are so regulated that the height $\frac{V^2}{2g}$ precisely correspond to the relative pressure of the boiler, the living force $(1+y)\frac{V^2}{2g}$ is effectually destroyed by the back pressure of the boiler; the introduction into the boiler will have no velocity, and the quantity of heat introduced will be definitely

$$(1+y)\int_\theta^\tau l dt$$

or about

$$(1+y)\ (\tau-\theta).$$

If the velocity V of the mixture is greater than that which corresponds to the relative pressure H, of the boiler, (measured by a column of water) the mixture will posess a certain living force

$$\frac{V^2}{2g} - H,$$

at its entrance into the boiler, but this living force becomes heat, in the motions which it occasions, so that no more heat can disappear than the quantity

$$AH\ (1+y).$$

Thus we know whatever the velocity V of the mixture there will disappear only the quantity of heat corresponding to the work

$$(1+y)\ H,$$

of the introduction into the boiler. This work comprises two terms :

y H and 1 × H.

The first represents the useful work in feeding; the second corresponds in reality to a quantity of heat which ought to be found in the heat of the mixture; this is a loss which is balanced by a previous gain made by the steam at the moment of exit from the boiler.

Suppose, then, that the velocity V of the mixture be precisely that which gives

$$\frac{V^2}{2g}=H,$$

so that the introduction of the mixture into the boiler be made without velocity; determine, by experiment, the quantity of water raised y, its temperature τ' and calculate the same temperature by the formula (E). The heat which should be brought back to the boiler, is, theoretically

$$(1+y)\ (\tau-\theta),$$

The heat brought back is, in reality,

$$(1+y)\ (\tau'-\theta).$$

There is then, practically, a loss of heat

$$(1+y)\ (\tau-\tau').$$

Add to this loss the loss of heat resulting from work accomplished

$$\frac{AV^2}{2g}y,$$

We have for total loss

$$(1+y)\ (\tau-\tau')+\frac{AV^2}{2g}y.$$

This waste of heat applied to the introduction of y kilogrammes of water into the boiler, gives for waste of heat per kilogramme:

$$i=\frac{1+y}{y}(\tau-\tau')+\frac{AV^2}{2g} \quad . \quad . \quad (F)$$

Here is an experiment given by M. Reech. M. Giffard succeeded in feeding a boiler at five atmospheres, by conveying a weight of water equal to fifteen times that of the steam. The temperature of the mixture was 48°, the affluent water being 13°. We have then, in this experiment:

$$\theta=13°$$
$$y=15.$$

The formula (E) gives

$$\tau=53°,01.$$

Now then, the experiment indicates

$$\tau=48°.$$

Consequently,

$$\tau-\tau'=5°,01.$$

Now the waste of heat per kilogramme of feed water, is, (equation F):

$$i=\frac{16}{15}\times 5,01+\frac{41,32}{424}$$
$$=5,34+0,097=5.44 \text{ heat units.}$$

This number represents $\frac{1}{100}$ of the difference of temperature $(\tau-\theta)$.

This quantity of heat really disappears and is not found again. All other quantities of heat carried out of the boiler by the jet of steam y have been returned by the mixture.

Now, consider an ordinary supply pump, which introduces water into the boiler, at the temperature of 13°. This pump is operated by the engine, and produces useful work,

AH,

(H=height of water corresponding to the excess of the boiler-pressure over that of the condenser) per kilogramme of feeding-water, but it utilizes only a fraction k of force by reason of the friction or resistances of various kinds.

Now this force is only that of the steam; and we know that ordinary non-condensing steam engines use scarcely three parts in 100 of the heat transmitted to the boiler; then the introduction of a kilogramme of water into the boiler, by means of a feed-pump requires an expense of heat of

$$\frac{1}{0,03}\ \frac{AH}{k}.$$

The co-efficient k of the ordinary pump is 0,50, consequently this quantity of heat has for its value

66, 6 AH.

Observe that the water introduced is not of the temperature θ of the supply reservoir. To raise the temperature of this water from θ to τ it will be necessary to consume a quantity of heat $(\tau-\theta)$, but as the heating apparatus never uses but $\frac{2}{3}$ of the heat developed by the combustion there will be $\frac{1}{3}$ of the heat lost. The total consumption of heat will be then,

$$j=66,6\ AH+\tfrac{1}{3}\ (\tau-\theta).$$

By feeding by means of an injector, we had found the loss of heat to be,

$$i=0,155\ (\tau-\theta).$$

It is easy to see that the first is the more important. Suppose, for example, a pressure of five atmospheres, we will have :

$$H=41,32,$$
$$\tau=48^{\circ},$$
$$\theta=13^{\circ},$$

$j=18.20$ heat units, $i=5.44$ heat units.

In this case, the cost of feeding by means of an injector is less than one-third of that of feeding by means of a pump.

These results would be somewhat modified if we had the use of a good condensing engine. Here the work of the engine is 10-100; that of the pump, if well established, 60-100, introducing water from the condenser at a temperature of 50°. The injector should work equally with the water of the condenser. We should always have $y=15$.

The value of τ resulting from equation (E) would be

$$\tau=87^{\circ},70,$$

If we admit that the loss of heat by the injector will be more than 15,5-100 of the difference $\tau-\theta$ we will have for this loss

$$i=0,155\times37,7=5 \text{ heat units, } 84.$$

The loss of heat from feeding by means of a pump, and of heating the water from 50° to 87°,70, will have for value

$$j=\frac{1}{0,10}\ \frac{AH}{0,60}+\frac{1}{3}\ (87,70-50)=14.12 \text{ heat units}$$

This is more than double the number 5.84 heat units. The economic advantage is always on the side of the Giffard injector; and this apparatus possesses also a great simplicity in adjustment and working, and an important economy of heat. The injector gains from nine to thirteen *calorics* per kilogramme (heat units) of water introduced into the boiler.

THE GIFFARD INJECTOR EMPLOYED AS A PUMP.

The Giffard injector is a suction and forcing pump, but its mechanical performance is weak, because the greater part of the heat is employed in raising the temperature of the water. The expression of the mechanical rendering per kilogramme of wasted steam, is,

$$y\frac{V^2}{2g},$$

and its calorific equivalent

$$y\frac{AV}{2g}.$$

We have inserted in the table the values of the product $y\frac{V^2}{2g}$ for the different cases.

We see, by an inspection of the table, that the velocity of the mixture varies from 0 to 97^m, 29, that it corresponds to the height of water from 0 to 482 metres. Consequently we are able to introduce water into a reservoir against a pressure of,

$$\frac{482}{10,33}=\text{about } 46 \text{ atmospheres.}$$

The mechanical work $y\frac{V^2}{2g}$ augments with the velocity. At the temperature 100° of the mixture, there are 3,063 kilogrammetres per kilogramme of wasted steam. If we compare this number with those of the preceding table, we see that it is only one-eighth of the theoretical work of steam in a non-condensing engine. The mechanical work would be only third of that which would be performed by a pump placed in the same conditions for the same purpose.

If we take the numbers corresponding to the temperature of 40° of the mixture, temperature for which $y=22,70$, $V=30,17$; the mechanical work produced is no more than 1,053 kilogrammetres.

It is reduced to the third of that which it was for $\tau=100^{\circ}$.

Considering, in a general manner, the Giffard injector as an exhausting pump, the problem ought to stand thus :

The height to which it is necessary to raise the water being given, what will be the mechanical performance of the injector?

At first sight it is clear that we wish to place the apparatus at the greatest possible height above the reservoir to be drained. In doing this we diminish the pressure in the chamber BB, (Fig. 2). Consequently, we lower the temperature

t of the steam jet, which is nothing more than the temperature of saturation corresponding to the pressure in the reservoir BB. The raising of the water into the chamber BB, will be the same as raising it in a suction pump. We should be able then to raise it to the ordinary

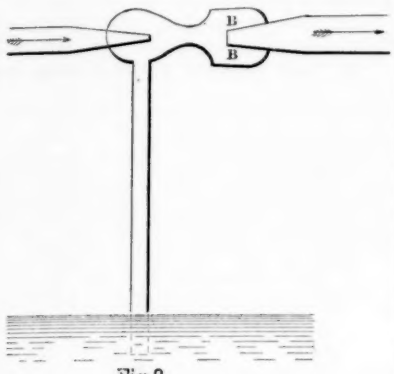


Fig. 2

practical limits, that is to say, eight metres. Under these conditions, there will be the greatest possible fall of the temperature of the steam from the boiler to the orifice of the injector. We shall have the maximum of mechanical effect, and there will be, between an injector working thus, and an ordinary feeding injector, when the steam is at about 100°, the same difference as between a condensing, and a non-condensing steam engine.

The height being eight metres, the pressure in the chamber BB will be

$$10{,}33 - 8^{m} = 2{,}33 \text{ of water}$$

or

$$176^{mm} \text{ of mercury.}$$

The temperature of corresponding saturation is about 63°. Going back to equations (D) (E), we will have for determining the minimum of the velocity of the mixture the equation

$$\frac{V^2}{2g} = h.$$

Equation (D) will give us

$$V\left(V - \frac{W}{(1+y)}\right) = -8g,$$

from these two equations we deduce

$$1 + y = \frac{Vw}{V^2 + 8g} = \frac{\sqrt{hw}}{\sqrt{2g}} \Big/ \frac{h+4}{} \qquad (G)$$

The weight of water raised will be the greater as w will be greater. Now, the initial and final temperatures of the steam, during its flow, being determined, w depends only upon the moisture of the steam. The quantity of water raised will be greater in proportion as the steam is dry.

The mechanical work produced by the apparatus will be

$$\tau = y\,(h+8). \qquad (H)$$

Here is a table of quantities of water raised by an injector pump placed at eight metres above the exhausting reservoir, and fed by dry steam at five atmospheres:

	Injection of Dry Steam at 152°,82. Velocity, w=930m.		
Total Height of Elevation.	Weight of Water raised per kilogram. of Steam used.	Mechanical Work obtained.	Temperature of Water raised.
$h+8$	y	W	τ
		km.	
1+8=9	41,0	369	"
10+8=18	46,37	835	"
50+8=58	26,47	1535	"
100+8=108	19,18	2071	"
200+8=208	13,51	2810	"
500+8=508	8,30	4216	"
800+8=808	6,89	5163	100°

This table shows that the mechanical performance of the injector pump increases rapidly with great heights, otherwise it is inferior to ordinary steam pumps. It is then for great elevations that the injector gives most satisfactory results. It would be little economy to employ it in common use, but it would be very useful for draining exceptional leaks in mines, when the ordinary pumps are not sufficient. The extreme simplicity of this kind of apparatus will often give it the preference over others that do more perfect work.

We ought again to remark the importance of placing the injector at the height of eight metres above the reservoir.

Whereas, in the first table we have found a performance of 3,063 kilogrammetres for an elevation of 482 ^{m},3 the injector being at the level of the reservoir; the table above gives us a performance of 4,216 kilogrammetres for a height nearly equal to the former—that is to say, 508 metres.

DRAINING SMALL DEPTHS WITH THE INJECTORS.

Steam injectors are employed at the side of vessels for draining leaks in the hold. Under these circumstances the total height of lifting varies from five to ten metres, and each kilogramme of expended steam furnishes about 900 kilogrammetres. Now, in a ship's engine, one kilogramme of steam produces about 17,000 kilogrammetres, according to M. Freminville's treatise on Marine Engines. A pump in the hold would perform only one fourth of this work, according to that, one kilogramme of steam would produce a useful work of 4,250 kilogrammetres.

Compare the number 900 kilogrammetre with this last, and we shall find the ratio of the work of the steam injector to that of the pump,

$$\frac{900}{4250}=0{,}211.$$

According to M. Freminville, this number should, in practice, be diminished to 0,16.

THE IRON MANUFACTURE OF RUSSIA.

From "Iron."

THE importance of the iron trade in modern States is such that their economical condition may be said to be definable by its extent and development. Every State is glad to see this particular manufacture prosperous within its borders, and in various ways favors it. Russia seems to have been attracted by the example of America in endeavoring at the present time to free herself from dependence upon external aid, the need for which has hitherto made itself felt in the supply of the large quantities of iron needed for the permanent way now in construction in Russia. There are two economico-scientific societies in the country which have the special task of watching over and furthering the interests of Russian trade and manufacture: these are the "Society for the Promotion of Russian Industry and Commerce," and the "Technical Society;" both are active bodies with a large number of members and correspondents. They are both based on principles of protection, which it is part of their duty to make known. The latter of these societies made the subject of its last congress, the means of elevating the condition and extending the resources of native ironmakers and machine builders. To this congress the members of the trades interested were invited; they were unanimous in concluding upon the desirability of raising the import duty on iron. It remains to be seen whether the Russian Government will agree with this conclusion or not; but it is not unworthy of note that the president of this society is no less a person than Prince Constantine, the Emperor's brother. His presidency is an actual, virtual one, the discussions of the society being under his chairmanship. To the joint action of the two societies is due the existence of the technical museums of St. Petersburg and Moscow, which have been abundantly supplied with carefully selected specimens of the mineralogy and metallurgy of Russia.

The collection at the Polytechnic Museum in Moscow is deserving of special mention. It shows in a very complete and striking manner the mineral capacities of the country, its geological peculiarities, and the development of its mining and metal-working industries. The models of mining tools, machinery and apparatus, and the completely classified ores, are of great interest. The contents of this museum, as a synopsis of the geological characteristics and mining capabilities of Russia, will,

together with official returns, be our guide in this sketch.

The largest number of mines and furnaces are to be found in the Ural Mountains, and the whole department of the Ural. Most of these have been called into existence by the Government. Together with the Government mines are many private holdings, which pay dues to the Government. The payment of royalty dates to the times anterior to the abolition of serfdom, when mining concessions—ground and serfs together—were made against payment of a five per cent. royalty in addition to the usual ten per cent. tax on gross returns. These works now pay a fixed sum yearly, the Government having capitalised its demands. The province of Olonetz in the north, as well as Ekaterinoslav in the south, and Poland, also pay considerable sums on account of mining concessions therein. Private works on a large scale exist in Kaluga, Tula, Vladimir, Kostrama, Nijegorod, Scusa, and Orel Jonner, in Minsk, Wilna, and Mohilno, and lately a good many similar works have been opened in Finland and Poland.

On looking closely into the condition of the Russian iron manufacture we find it in a very defective condition, compared with that of Western Europe. The Government works give no financial result, in consequence of their bad administration, and private establishments appear to lack energy. In a country like Russia, rich in minerals and cheap labor, very different results ought to be shown from those actually attained.

Perhaps there is one ground of excuse which has to be admitted. Fuel is scanty: wood is dear; and the ways between the mine and the furnace are frequently defective, and always difficult. The forests of the Ural are growing thin, and the coal fields are insufficiently worked and scantily provided with communications. So long as these hindrances stand in the way, any measureable extension of the Russian iron manufacture is impossible. At the exhibitions last held in St. Petersburgh and Moscow, an endeavor was made to put Russian charcoal iron in as favorable a light as possible; since, with all due regard to quality, only the prices of the works of Olonetz, and Finland, places comparatively near the metropolis, were slightly more advantageous. The exhibition of ores from these places was very rich; fresh pits are being opened almost daily. The thirty new specimens of Finland ore show a high percentage of iron, ranging from seventy-two down to fifteen. Rachette's system of heating is adopted in Finland, and from the enterprise shown by that province, there are good hopes of its success.

The following qualities are compiled from official returns for 1874. In that year the Government works in the Ural, in Olonetz, Poland, and South Russia, produced: cast-iron 202,501 tons; wrought iron, 8,994 tons; steel, 1,151 tons; shot and shell, 8,203 tons; steel cannon, 146 tons; iron cannon, 241 tons; various other goods, 106½ tons; armor plates, 169 tons; locomotives, 177 tons; steam ships, 121 tons; swords and bayonets, 46,695; gun barrels, 5,725; percussion tubes, 577,401. Private works produced:—In the Ural: cast iron, 227,419 tons; wrought iron, 164,164 tons; steel, 1,121 tons; Central Russia: cast iron, 54,090 tons; wrought iron, 29,596 tons; Poland: cast iron, 22,155 tons; wrought iron, 13,064 tons; South Russia: cast iron, 7,062 tons; wrought iron, 7,121 tons; other parts of the empire: cast iron, 1,270 tons; wrought iron, 6,194 tons; steel, 4,193 tons. The average total production of Russia for some time past has been from 306,500 to 322,600 tons per annum. Two-thirds of this total are produced in the Ural.

Although both East and West Siberia are rich in ores, they lie fallow, and a large proportion of the make of the Ural goes to Siberia. The one and only means for raising the iron trade of the latter district is in the use of mineral fuel. In certain parts of the Ural coal is found in ample supply, and needs only energetic measures to be taken for its extraction, and a sufficient railway system to provide for its distribution. Of these facts the Government is already well aware. It should be particularly pressed upon it to pay great regard to the abundant supplies there are of magnetic ore. In this connection is to be mentioned the mineral district of Goroblagodat, on the slopes of the Ural. Goroblagodat is a rocky mass, formerly covered with forests. It is perhaps the richest mineral district in all Europe. The wealth of this district was not

known until the beginning of the eighteenth century; and the first workings there were not opened until 1730, in the reign of the Empress Anna. The summit of the hill is 490 feet higher than the Kushva workings, and is a mass of porphyry syenite, upon which, on the east side, lies a deposite of magnetic ore, 280 feet thick, descending to an unexplored depth below the bed of the valley. At the foot of the hill is a stratum of syenite, stretching half way up its slope; upon this the naked ironstone is piled to the summit. As the ore lies thus exposed extraction is effected in the simplest manner, with quite primitive tools. Even in the pits which have been sunk for the purpose of getting a more compact ore there is no difficulty in extraction. The workings have so far yielded 36,000 tons of mineral a year, which are smelted in five blast-furnaces in the neighborhood. The registers of the mine were burnt in 1813, and the available data concerning this mountain of ore do not go beyond that year. Reckoning by analogy, the total output must have been 1,600,000 tons; since from 1813 to 1872 there were raised 1,290,322 tons. The store yet unexhausted is estimated at 6,400,000 tons.

The Polytechnic Museum in Moscow possesses a rich collection of ores from this district as well as from that of Tagile, and from the so-called magnetic mountains of the Southern Ural. The latter district is distinguished for its magnetic ironstone; the museum also contains brown ironstone from the district underlying Moscow to the south, and from Poland and Finland. The coal resources of Russia we may make the subject of a later communication; for the present we content ourselves with the observation that capital and enterprise have here the prospect of large earnings, which the building of railways between the coal and iron fields would help materially to increase. The only works using coal, which we have now to mention, are the Bank of works in Western Poland (making 2,260 tons of pig a year), and the Lissischauk works in South Russia, province Ekaterinoslav. The latter are Government works; they were founded, in 1866, as a model establishment to stimulate private industry, and to encourage the opening up of the Donetz coal field. Two private establishments were called into being by them —the New Russian Company, a joint-stock concern in Ekaterinoslav, and that of Pastukhof, in the government of the Don Cossacks. Local coal only is burnt in both these latter, as in the Government establishments.

Coal is used for making wrought iron only in certain works of Western Poland, in the Imperial works at Kamkofsky (Viatka), and those of Lugan, in the province of Ekaterinoslav. In rolling mills coal is employed only at the Alexandrofsky Works, owned by M. Usevolojsky, and those of M. Lazaref in the Ural. Technical methods are a little too prone to keep the *status quo ante;* modern improvements are not much regarded, if we except Siemens puddling furnaces, which are found here and there. Notwithstanding, heavy work has been done; stout boiler-plate has been made, and armor-plates, 15 inches thick, and weighing 1300 pood, have been rolled. The rail manufacture is in a low condition. This is to be regretted, as the railway wants of Russia are very large. The largest rail-making house is that of Pantiloff, at St. Petersburg. It produces an annual average of 1,000,000 pood of rails and 200,000 pood of other articles. The works occupy about 2000 men; the coal used, as well as the cast and wrought iron, are imported from England. Of the former, 20,000 tons, of the latter 11,000 are worked up annually, together with from 6000 to 8000 tons of old rails and scrap. In the government of Nijni, in the Ural, as well as in South Russia, there are a few rail mills, but they are of small importance. With the other Russian works are to be enumerated those, ten in number, belonging to the "English Vicksounsky Company;" eight of these are in the government of Nijni Novgorod and one in Tambouf. The company smelts its own ores, employing about 3000 workmen, and producing bar, sheet and wire. The largest owner of mining property in Russia is Mr. Paul Demidoff. The whole city of Nige Tagilsk, in the Ural, belongs to him; his head offices, wherein is transacted the business of thirteen mines and works, are here. His possessions extended over a million and a half acres, and consist of mines of ironstone, manganese,

copper, lead, gold, platinum and diamonds. Bar iron and boiler-plates are the chief products, steel is unimportant; the total make is 21,700 tons. Steel-making is beginning to progress in Russia, especially the making of crucible steel, which is used for steel cannon; in this connection we must mention the Imperial Perne and Obukhof Works, at St. Petersburg, which are under the control of the Admiralty. The manufacture is carried out in strict accordance with the most advanced requirements of science. The Bessemer system has not yet been commonly introduced; Pantiloff was the first to adopt it in Russia, he was followed by Demidoff, Bernadacky and Obukhof. The two latter have also adopted the Siemens-Martin system.

Ninji Novgorod is the principal market for the Ural iron, so far as concerns merchant irons and iron goods; pig-iron does not pay for freight. Most of the Ural works lie within range of the network of the Volga, and are thus in tolerably easy communication with their market. The works in the departments of Vladimir and Nijgerod also bring their goods to Nijni Novgorod, the total amount brought there being estimated at 150,000 tons. Heavy goods are forwarded from the works in flat-bottomed boats, several of which are joined together and called a river caravan. They float down the tributaries of the Volga into the main stream, rarely getting into it without risk and never without trouble. The iron sold passes through two pairs of hands before it comes to the retailer, the difference between consumer and producer sometimes rising as high as 9s. per cwt. The prices of merchant iron are regulated by the weather and the results or prospects of the crops. This is accounted for by the fact that agriculture in the neighborhood of the mines is on a very small scale, and its products are inadequate to the wants of the inhabitants and the workmen, so that the larger portion of the food consumed in the Ural has to be brought, at great expense, from a distance. In the interior of Russia the patriarchal system necessary during serfdom is still retained, and owners and principals take the material necessities of their workmen into consideration. They are in the habit, accordingly, of laying in a twelvemonth's store of provisions for their employés, and retailing to them at cost price; the prices of iron and of agricultural produce are thus brought into an interdependence. The iron brought to Nijni Novgorod is carried north as far as Riga and south as far as Odessa. The south-west part of Russia takes the make of the works at Tambof, Riazan, Vladimir and Kaluga direct. The governments south of Nijni get their iron from Laishef, in Kasan, a halting-place for the Siberian caravans.

A SCHEME for a United Drainage District for Birmingham and the surrounding places has been adopted by the joint committte, subject to confirmation by the various sanitary authorities within the united district. The district proposed is to include Birmingham, Aston, Balsall-heath, Handsworth, Harborne, and Smethwick urban districts, part of West Bromwich urban district, and parts of the rural districts of West Bromwich, Solihull, King's Norton, and Aston, and such other places or districts as the Local Government Board may think fit to include.

The objects of the scheme are:

(1) The disposal of the sewage of the various towns and places within the district in such a manner as shall prevent the pollution of the river Rea, and the river Tame, and any of their tributaries.

(2) The prevention of the pollution of such rivers and tributaries from any other cause, either within the district, or previous to their entering the district.

The board is to take charge of outfall works for the whole of the district, and of such intercepting sewerage works as may be necessary to convey the sewage of each town or place from the main sewer to the boundary of the outfall works. The local draining of each town or place will not be included in the powers of the board, but the board is to define the boundary of all outfall works which may comprise tanks or works for subsidence, filtration, or other treatment for the purification of sewage, and land for the purposes of irrigation, filtration, or utilisation of sewage.

THE PROFESSION OF ENGINEERING.*

By Professor FLEEMING JENKIN.

From "Engineering."

Gentlemen, — On considering the addresses which I have had the honor to deliver in this university, I found that I had never spoken in praise of the profession which you have entered. Perhaps the omission was due to an unconscious pride grounded on the conviction that no one could doubt the value of the work done by the engineer; nevertheless, you may perhaps be glad to listen for once to the eulogy of our common occupation. Nor will my words be useless if they serve in any degree to fan the enthusiasm with which, as I hope, many of you are entering upon the business of your lives.

Let us consider why a man who needs to gain his daily bread should select one profession rather than another. Putting aside commonplace motives, such as are afforded by the existence of family connections or interest, I think a man will choose his occupation wisely if in it he seeks to find scope for the healthy activity of his best faculties, and the satisfaction due to the knowledge that his work will benefit others as well as himself. Some definition of the business of an engineer must be given before we can discuss how far our occupation fulfills the conditions now laid down, and I think that I shall hardly make that definition too broad if I claim as our special work the practical application of science to the satisfaction of man's material wants. Food, clothing, and shelter, light and heat, air to breathe, water to drink, these are the first material wants of man, and wherever science aids in their production or distribution there the engineer steps in. Exclude science and the definition fails; the husbandman sowing and reaping after the manner of his fathers, is not one of us, but already by right of science we claim his sons as our subjects; we plow, we sow, we reap, and agriculture henceforth is ours. Similarly, wherever exact knowledge replaces traditional art in the production of any fabrics or manufacture, the head and hand of the engineer apply the means. The mill then replaces the solitary worker, and it is the engineer who builds the mills, who fills the mills with his machines, who drives the mills with his engines, who carries the materials in his steamers and his railways, which again serve to distribute the produce to man. In all these cases we simply apply science, that is, exact knowledge to production or distribution. The means of attack and defence are among the material wants of man, and although we are not soldiers, yet it is we who now arm the nation. Shelter is one chief material want; it is the duty of the engineer to provide buildings so constructed as to be healthy. Drainage, warming, ventilation, all lie within our province, since all these subjects require applied science. The simple builder may repeat the traditional house, the architect may adorn where he is able, but it is the engineer who must use the discoveries of the philosophers to improve the health and increase the comfort of his fellows. We see already that the scope of the engineer is certain to be wide, and on considering what branches of science fall within his province, our conception of his field of action will be still further enlarged.

Mathematics and natural philosophy need only be named to be accepted as heading the list of our servant sciences. Chemistry finds its application in the improvement of manufactures, in mining, in sanitary engineering, and if any chemist not an engineer should claim exclusive jurisdiction over certain useful applications to the improvement of manufactures, I would first observe that in applying his ideas he requires our machines; and secondly, I would point to the progress made when a Bessemer or a Siemens is at once engineer and chemist. I claim that every exact science, by which I mean every science the results of which can be numerically expressed, requires for its application to the wants of mankind the assistance of the engineer.

* Address delivered at the Opening of the Class of Engineering in the University of Edinburgh, November 1st, 1876.

Passing to what may be termed the historical sciences. It is the engineer who *uses* geology whether in mining, in the construction of roads, or the collection of water. If I think of botany, I say that our foresters should be engineers. It is the engineer who applies the teaching of physiology to the improvement of our dwellings and to the purification of our rivers, and thus we see that if these historical sciences are less exclusively our own than those which deal with numbers, yet we may say that wherever any science whatsoever is concerned with production or distribution, the engineer cannot be repelled as an intruder.

No man who loves exact knowledge can fail to find scope for the exercise of his intellect in the practice of the engineer. This practice is, moreover, curiously suited to men of the most opposite temperament. The sedentary man can work in his study, the active man need hardly leave the field; the man who loves home life may find abundant work in quiet country towns, the adventurous man may push his fortune in distant almost in desert lands. The man of routine and method who loves to do well that which has been done before, will find himself popular, while the inventor who creates new wants and new wealth is the idol of the profession. The recluse who loves solitude may work in peace, but the born ruler of men may command peaceful armies. The cautious man will meet with praise and the bold financier may dispose of the savings of a nation. The sense of beauty is not required, but if any one of us should possess a taste, unfortunately too rare, his scope might be envied by the greatest artist. The man of high education commands resources of inestimable value, but the simple workman who can observe nicely and reason accurately may take the place of a leader. Language, letters, rhetoric have been gifts denied to many of our greatest men. Yet the linguist possesses great advantages. The man of letters is certain to find readers and the speaker to collect an audience. Many a contented engineer lives out a useful life administering a system of tradition, while his ambitious brother directs schemes which may change the face of a continent and found the prosperity of nations. Two conditions, and these only are needed, the man must love his work, and have ability to perform it.

Let us then take it to be true that the man who loves science in any of its branches and takes pleasure in its practical application may as an engineer find ample scope for the exercise of his intellect. There still remains the question: May he find in that exercise the solid pleasure of believing that he is working for the general good? To many of you the question may seem almost idle, but at some time or other to older men the question will at times occur, Why am I working? Am I not disquieting myself in vain? Money making is no great pleasure when once bread for the family has been earned; social distinction is like the fair fruit filled with ashes. If as older men you are to work with the fire of youth, other motives are needed, and it is no idle question to ask whether in our profession these other motives will rise and lead us on. I for one do not doubt it. By our work we feed mankind, we clothe mankind, we house mankind. Through our work deserts are peopled and old countries teem with a new life. We promote wealth which in its simplest sense is but well being. Let who will look backward on a past golden age embellished by a haze permitting imagination to people its pastures with idyllic beings. We face the present with faith in a future moulded by knowledge of the truth. If the husbandman does well producing food, the engineer doubling that food does better. The charitable man gives bread but the engineer gives work whereby freemen may earn their bread. When the engineer cheapens cloth he betters the condition of man more than if he halved his cloak with a beggar. To cheapen dwellings is better than to build an almshouse. If existence be a boon, and I do not doubt it, the engineer is indeed a benefactor, his creations have called peoples into existence, he creates wealth and wealth creates men. These things I hold to be his greatest deeds. I almost reluctantly speak of the more direct benefits he confers by giving pure water, fresh air and cleanliness to the dwellers in towns. The direct action of the sanitary engineer is more visible, but is not really more beneficial than the work of all other branches of the pro-

fession. The man who by a better form of bearing diminishes friction thereby cheapens production and clothes the poor. Our business is to supply the material wants of men, and he who can do this is doing well.

Though I claim much, do not suppose that I claim supremacy for our work, or call on all to join us. We do good, and we have great scope, so much I claim fearlessly, but I neither say we do the chief good, nor that we have the widest scope. It is well to remember that man does not live by bread alone, and if the engineer can create a nation he can do but little to determine what manner of nation it shall be. This duty falls to men whom some may call prophets, some poets, some philosophers, some the divine teachers of mankind. We, the men of exact science, seeking for material good, do not belong to this band; we can only print their words, spread their doctrine, and follow their guidance. We miss, too, the direct sense of alleviated suffering which must be the physician's chief reward; but yet our steamers fetch his drugs and our mills prepare them. The arts which are concerned in the production of beauty, are all, save one, strangers to us, and even although the province of architecture is our natural heritage, we have failed to claim our right. The history of the great past is of little account to us, neither is it our task to mould or to administer the laws which regulate the relation of man to man.

Nevertheless, although these things do not lie in our province, although we may grant that higher duties may fall to other men with greater gifts, yet we may be pardoned if we remember that where there be prophets they will prophesy falsely, that the physician still walks by an uncertain light, that the lawyer may become the slave of words, and the politician may blight where he would fain bless, whereas I believe that I am making no idle boast when I claim that if we as engineers labor diligently in our vocation, whether our opportunities be great or small, we shall not labor in vain.

HYDRAULIC PROPULSION OF TRAMWAY CARS.—About midway on a line or network of tramways, or at any other point of the same line, a motive-power engine is, according to the invention of M. L. Rousseau, C.E., of Brussels, mounted and arranged in combination with pumps and apparatus in a similar manner to those employed in ports, docks, or warehouses, where the lifting apparatus are actuated by hydraulic pressure. For this purpose a pipe or tube for conducting water under pressure is laid down along the whole of the line of tramway or its branches, and in communication with a reservoir or receiver. At suitable distances apart valves or taps are placed in the said pipe or tube in order to supply water under pressure to the carriages of the train, which are placed at certain stations in communication with the reservoir or receiver above mentioned. At these different points or stations each carriage completes or renews and stores away the necessary quantity of water under pressure which is required to enable it to act automatically in the distance comprised between two hydrants for taking in the water.

In order to maintain the water under pressure stored in each carriage, a receiver is fixed either horizontally or vertically under the floor of the carriage. This receiver is composed of one or more cylindrical metallic vessels containing compressed air at high-pressure (from 20 to 30 atmospheres), according to the power required. The compressed air contained in each receiver acts by its elasticity similar to a spring, either direct or by means of a piston, on the water supply contained also in one or more cylindrical vessels. The water under pressure in the reservoirs or receivers puts in motion the mechanism, and thereby gives rotary movement to the wheels of the carriage. In order to put the mechanism in motion, an ordinary hydraulic capstan is employed, or the well-known multiple cylinder apparatus of Brotherhood or West, or the well-known cyclo-dynamic machines of Mathon, or any other suitable mechanism, in order to obtain the same result.

ULVERSTON FURNACES.—One of the three furnaces built by the North Lonsdale Iron and Steel Company, at Ulverston, has been blown in, and the remainder are expected to be lighted in a short time.

TRANSMISSION OF POWER BY WIRE ROPES.*

By ALBERT W. STAHL, M. E., Cadet-Engineer, U. S. N.

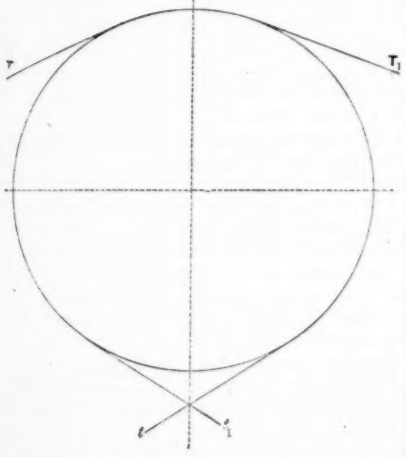
III.

Section X.

PRACTICAL DIFFICULTIES.

In the transmission of power by wire ropes, the greatest attention must be paid to keeping the ropes and the lining of the wheels in thorough repair. Even when the ropes are exceedingly taut on the wheel at first, it has been found by experience that, after a short time, the ropes stretch considerably. This causes the ropes, particularly in summer, to sag

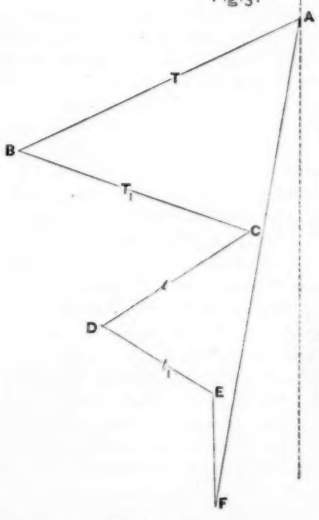
Fig. 30



so much as to incapacitate them from transmitting the whole force, causing them to slip on the wheels; or the ropes begin to drag on the ground or other obstructions. This evil may be partially remedied by shortening and again splicing the rope, which, however, should be avoided as long as possible, as the rope is ruined more rapidly by several re-splicings, than by long running under the regular working tension. I must remark that a wire rope stretches more as the wires make a greater angle with the axis of the rope; but as a rope having its wires parallel to the axis would be useless, we must strive to keep the angle at its minimum value.

Experiments made with a view to stretching the ropes before putting them into use have not been very successful. It is only lately that the problem has been partially solved by a method of compressing the ropes while subjecting them, at the same time, to a great tensional strain. Wire ropes with wire centers, as sold in the market, are stretched in this manner from .22 to 1.2 per cent.

Fig. 31



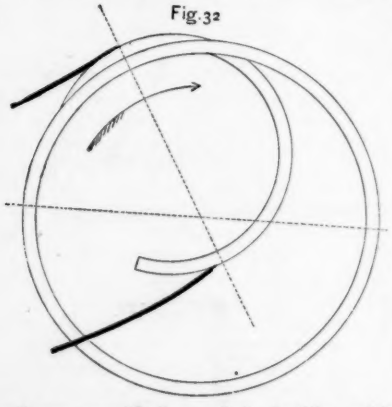
Wire ropes with hemp centers, as generally employed for the transmission of power, are stretched from .71 to 2.6 per cent. of their original length, without at all impairing their strength.

Although this is a great step in advance, reducing the stretching of the rope, with its accompanying disturbances, to a minimum, yet even this is not sufficient to maintain a constant tension and deflection in the rope, and we are often compelled to use other means to restore to the same its original tension.

* A graduating thesis at the Stevens Institute of Technology, Hoboken, N. J., June 30th, 1876.

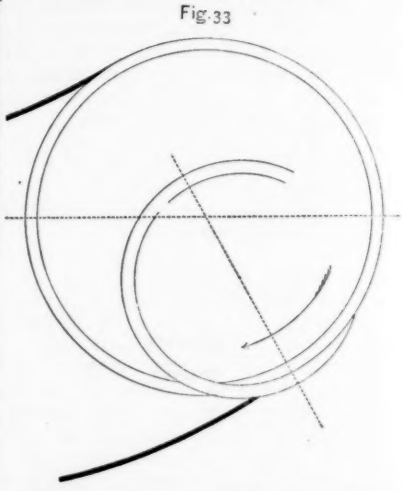
The simplest and most effective way of attaining this end is by re-filling the rims of the wheels, *i.e.*, by increasing their respective diameters to the proper amount, which is done in the following manner. (See Figs. 40–43.) Fig. 40 shows the cross section of a wheel with leather filling, and Fig. 41 the same wheel with its diameter enlarged by the superposition of the new filling, which is best made of poplar or willow-wood. It is made by taking straight pieces of about 1¼ inches in thickness, planing them into the necessary shape to fit the rim of the wheel, or merely cutting them into that shape by means of a circular saw, and providing their upper surfaces with grooves for the ropes. These pieces are made from 45–70 inches in length,

Fig. 32



and are provided on their insides with saw cuts going half-way through the wood. When we wish to put on this filling, the pieces are steeped in water for a day or two, to render them more flexible. They are then nailed to the leather filling by means of suitable wrought nails, which should be somewhat longer than the thickness of both fillings together, so that after passing through the leather they may strike the iron below and be clinched, thus affording a better hold. The nails must be driven as shown in Figs. 41 and 42, and especial care must be taken that there are no projecting ends within reach of the rope. The whole operation can easily be performed in an hour, without throwing off the rope. In case the filling of one wheel in this manner is not sufficient to accomplish the desired result, we perform the same operation on the other wheel. If this is still insufficient, the whole process is repeated with a second layer. When the rope has finally become of a constant length, which usually takes place in the course of a year, we may carefully remove all but the leather filling, and then shorten the rope to the proper length, allowing it to run on the original filling. After this treatment, there is usually no more trouble to be apprehended from this source, but there are some other difficulties which must be guarded against.

Fig. 33



When the transmission is in good running order, the ropes should run very steadily and without swaying laterally. If the latter does occur, it is due to one or more of the following causes, (leaving out of consideration the slight swaying motion produced by the wind, or by an excessive velocity);

1. When the wheels are not perfectly balanced or are not true circles.
2. When the wheels are not in the proper plane.
3. When the filling is in bad condition.
4. When the rope is too much worn.
5. If the rope has been badly spliced.
6. If the rope touches the ground or other obstructions.

1/ It is absolutely necessary to balance the wheels perfectly; as, if they are not well balanced, the centrifugal force, at the velocity with which they are driven,

exercises a very prejudicial effect on the bearings of the shaft, as well as on the rope. The bearings wear out faster and waste more power in useless friction, while the rope begins to swing, sometimes to such an extent as to be thrown violently against the side of the wheel groove thus wearing out very rapidly.

2/ In mounting a transmission, the greatest care should be taken to get the wheels in the same vertical plane, and the shafts perfectly horizontal, inasmuch as any deviation from this position immediately shows itself in the rope.

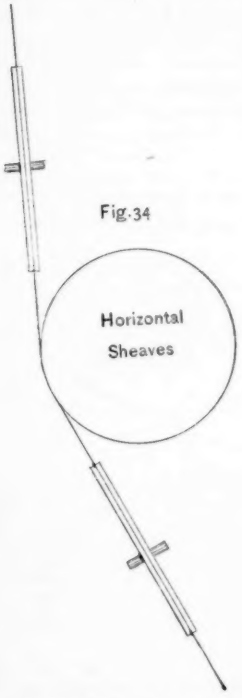


Fig.34

3/ In case the filling is in bad condition and worn unequally, it causes the rope to swing in a vertical plane. The remedy is to cut the filling so as to make it equally thick all around.

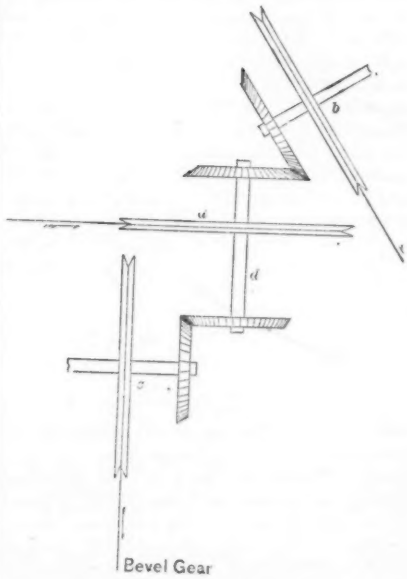
4/ If there are ends of wires projecting from the rope, then every time that one of these projections passes over the wheel, the rope receives a slight shock, causing it to swing. The same action takes place if torn or loose strands occur in the rope.

5/ If the rope has been badly spliced, or given a false turn, it will not run steadily.

6/ When the rope has stretched to such an extent as to touch the ground or other obstructions, it begins to swing violently. An attempt has sometimes been made to remedy this by putting in a little roller or guide, which, however, usually makes matters worse.

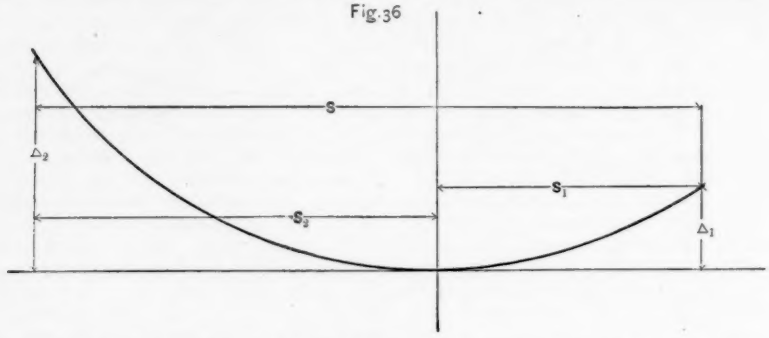
There are some other causes which induce an irregular action in the rope. For instance, if a wire rope is transmitting a constant power to a certain distance, and if the wheels, ropes, etc., are in good order, it will run steadily as long

Fig.35



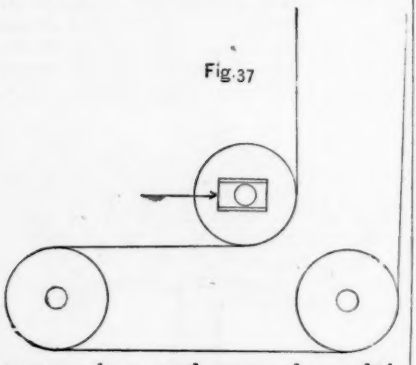
as the power transmitted corresponds to a certain tension and deflection in the rope. But now, if some of the machines are suddenly thrown in or out of gear, the tension in the rope and its corresponding deflection will be changed, thus causing the rope to sway gently in a vertical plane. The result is, of course, that the motor will change its speed to suit the new demand for power. This property is of great value, particularly in long transmissions, as it prevents sudden changes in velocity, the rope itself acting as a sort of governor.

Fig.36



Another cause of swinging is found in very powerful transmissions, where it becomes necessary to use two ropes to transmit the power, connecting the two wheels by a differential gear. The object of this gear is to equalize the tension in the two ropes, as neither this nor the diameter of the wheel can be exactly maintained in two wheels running side by side. As the cross-head of the differential gear is firmly connected with the shaft, while the wheels with their bevel-

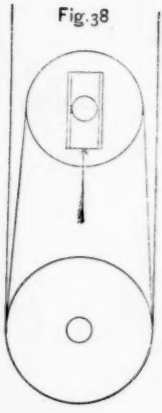
Fig.37



gear run loose on the same, the result is that when the tensions or the effective diameters of the wheels are not the same in both, there is an additional rotation of one or the other, caused by the differential gear. This produces slight vertical oscillations, which, however, have no prejudicial influence on the working of the ropes.

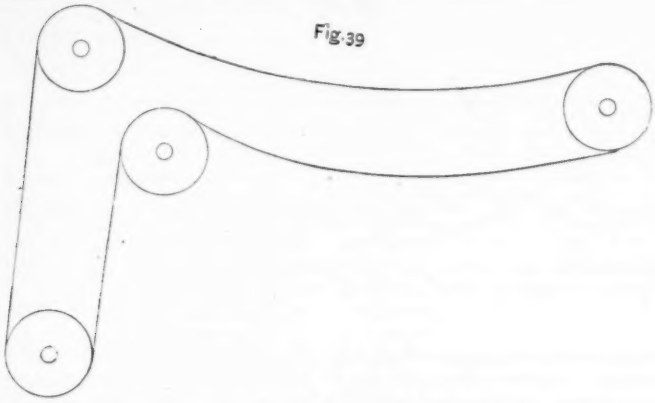
Wire ropes are sometimes used to transmit the power of a steam-engine to a distant building, or to combine its power with that of some hydraulic motor. In such cases, we must be very sure of the regular action of the steam-engine; as it often happens, particularly in the case of an expanding, single cylinder engine, with a light or badly balanced fly-wheel, that the speed during a stroke is irregular. If we attempt to transmit the power of such an engine by means of wire ropes, the result will be a series of oscillations in the latter, in synchronism with the stroke of the en-

Fig.38



gine. When this occurs, it can only be remedied by using a heavier and better balanced fly-wheel, or by adding a second cylinder to the engine. These irregularities come under the heading (1), because the effect of a badly balanced fly-wheel, is identical with that of a badly balanced driving wheel. When a rope is used in connection with a steam engine, the latter wants a very powerful, quick-acting governor, in order to prevent the overrunning of the engine, if the rope should suddenly break. Such

Fig. 39



an accident happened a few years ago in a cotton spinning establishment in Alsace, causing the complete destruction of a large steam engine.

Section XI.

Filling for the Wheels.

The filling first employed by Mr. A. Hirn, consisted of a strong leather belt, covering the whole rim and fastened to the same by wooden wedges. With wheels of large diameter, he was ob-

Fig. 40

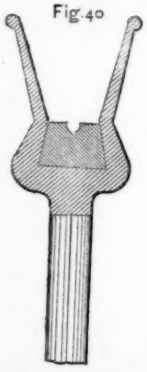
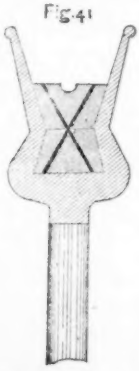
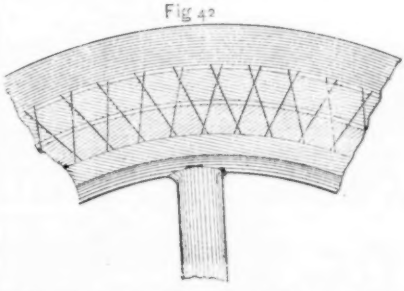


Fig. 41



liged to make this belt of several pieces, thereby weakening it considerably. This style of filling, however, rarely lasted longer than a few months. Hirn was then induced to try rubber, which has remained in considerable use up to the present day. But with very large wheels, the rubber was found to be unsuitable for the following reasons: Rubber expands greatly with heat, and when wheels filled with it are exposed to the direct and strong rays of the sun, the rubber becomes soft and is cut by the rope, or it expands over the edge of the wheel, causing the rope to be thrown off. In some cases, where the filling expanded greatly at noon, it returned to its original position during the night. On the other hand, there are cases known, when in cold nights during the stoppage of the transmission, the rope would freeze to the rubber filling. On starting in the morning, large fragments of the brittle rubber were torn out. Besides this,

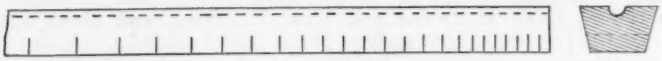
Fig. 42



rubber is also slowly dissolved by the oil and grease on the rope.

After some unsuccessful attempts at filling with hippopotamus skin, willow and poplar wood were tried, giving quite passable results. Strips of poplar wood about $\frac{1}{3}$ inch thick and seven to ten feet long were planed to the proper section, softened in hot water, and then driven in without any special fastening. This process was very simple, allowing the wheels to be re-filled quickly and at

Fig. 43



slight expense. The main difficulty was that the filling sometimes became loose, owing to the drying and shrinking of the wood during the hot season. This was partly prevented by driving pieces of wire through the filling and the rim of the wheel. The wood was also softened in hot glycerine instead of hot water, thus rendering it less subject to the action of the air. In spite of these precautions, a wooden filling rarely lasted more than six or nine months, when the wood was most carefully selected; while if knots or unsound spots were present in the filling, it wore out in a still shorter period. Various other woods were then tried, but willow and poplar were found to be the most durable as well as the cheapest. As wood wears less when subjected to strain and pressure across the direction of the grain, this method was also tried, notably at the immense Schaffhausen water works. In this case, small pieces were cut, having the fibre running from side to side of the rim of the wheel. These pieces were then dried thoroughly, and frequently immersed in linseed varnish until they were completely saturated with the latter, thus becoming more durable and air-tight. Notwithstanding these precautions, some of the pieces became loose, and, although more durable than the plain wood filling previously described, they did not last longer than about one year. A further trial was made with wood filling, in which the fibres ran radially, but with no better results. But this last method has the advantage that when the rope wears a groove into the wood, the sides do not split off as easily as in the two other styles. Cork has also been tried to some extent, but it was found of little value to transmit any considerable force, as it wore out very rapidly.

Again, by wedging the groove full of tarred oakum, a cheap filling is obtained, nearly as good as leather, and not so tedious to insert.

Another plan is to revolve the wheel slowly, and let a lot of small sized ratlin or jute-yarns wind up on themselves in the groove; then secure the ends. After a day or two of running, the pressure of the rope, together with the tar, will have made the filling compact.

The first attempts with the radial leather filling were made about 1865; and it was soon found that this method of filling was so decidedly superior to all others, that it has now come into almost exclusive use. It is easily inserted by any ordinary mechanic. The separate pieces of leather are driven hard against each other in the groove of the wheel. The key or closing piece is made of india-rubber, which is first softened in hot water and then driven into its proper place. The greatest wear of the filling occurs not, as might be expected, in the driving wheels, but in the carrying sheaves of an intermediate station, and there principally in the smaller pulley. This is due partly to the great speed, and partly to the fact that the perimetral velocity of the pulley is often greater than that of the rope itself.

The life of leather filling depends on the quality of leather used, and on the radial thickness of the pieces. It is also affected by the tension, and general condition of the ropes. It may usually be estimated at about three years.

Section XII.

EFFICIENCY.

The losses in the transmission of power by wire ropes are caused by several resistances:

1. The rigidity of the wire ropes in circumflexure of the two main wheels, and through the change of angular direction at either side of the carrying sheaves.

2. Friction of shafts of the wheel.

3. Resistance of the air to the rotation of the wheels and to the passage of the rope through it.

The loss due to the rigidity of the ropes may be regarded as insensible; because when the diameters of the pulleys are sufficiently large, the wires of which the rope is made straighten themselves by their own elasticity after having been bent.

The losses due to the friction of the

shafts, and the resistance of the air, have been determined theoretically and practically. Letting, as before, t' = working tension, t_0 = tension produced by bending, we have for the loss of power for the two main wheels, when

$\frac{t'}{t_0}$ =	$\frac{2}{7}$	$\frac{1}{2}$	$\frac{4}{7}$	$1\frac{1}{4}$	2	$3\frac{1}{2}$
loss=	.024	.025	.024	.022	.020	.016

The greatest loss .025 takes place when $\frac{t'}{t_0}=\frac{1}{2}$, as might have been expected; for we previously found this to be the condition for obtaining the smallest wheel. But even this maximum loss is a trifle. If we consider, that with favorable conditions, we can lead a wire rope from 500–900 feet without any intermediate support, while shafting of this length would cost an immense sum, besides being exceedingly inefficient, we can well appreciate the convenience and value of this method of transmitting power.

For the carrying sheaves the loss is as follows: when

$\frac{t'}{t_0}$ =	$\frac{2}{7}$	$\frac{1}{2}$	$\frac{4}{7}$	$1\frac{1}{2}$	2	$3\frac{1}{2}$
loss=	.0012	.0013	.0012	.0011	.0010	.0080

So that the efficiency in the most unfavorable circumstances, *i.e.* when $\frac{t'}{t_0}=\frac{1}{2}$, may be arrived at thus:

1. Overcoming the axle friction of the driving and following main-pulleys	.0250
2. Overcoming axle friction of each intermediate sheave	.0013

Hence the efficiency is E=.975—.0013 N, where N is the number of carrying sheaves.

Section XIII.

ESTIMATES.

It is impossible to give any definite idea as to the cost of erecting and maintaining a transmission. In France, where by far the greater number of applications are made, the cost of the machinery and its erection is estimated at 5,000 francs per kilometer, exclusive of the necessary constructions at the termini, which are said to require an additional expenditure of twenty-five francs per horse power.

The average cost is about one-fifth that of belting, and about one-twenty-fifth that of shafting.

But the number of carrying sheaves, distance, height of columns, etc., vary so exceedingly, that no more than a very vague idea can be given of the cost except by making an estimate for every special case. To make this a matter of ease, I have appended a list of the current prices of several articles, the first being the price of "Wheels bored to fit shaft and lined with rubber or leather":

Diameter.		Price.
$1\frac{1}{2}$ feet		$6.00 each.
2	"	8.00 "
3	"	25.00 "
4	"	33.00 "
5	"	53.00 "
6	"	75.00 "
7	"	95.00 "
8	"	125.00 "
9	" cast in halves	225.00 "
10	"	300.00 "
11	"	350.00 "
12	"	400.00 "

Special prices for larger wheels.

When the lining is worn out in these wheels, new filling, either of rubber or leather may be bought at 60 cents per pound.

The price of the ropes will be found in the wire-rope table previously given.

Section XIV.

HISTORICAL SKETCH.

The first transmission was put up by the brothers Hirn in 1850, at a calico weaving establishment, near Colmar. An immense mass of scattered buildings seemed to forbid the possibility of using them, and yet placing the motive-power at any one point. In this emergency, they first tried this method of force transmission, using a riveted steel ribbon to each building from the engine-house. The steel bands were about $2\frac{1}{2}$ inches wide by $\frac{1}{25}$ of an inch thick, and ran on wood-faced drums. This presented two inconveniences. In the first place, on account of its considerable surface, the band was liable to be agitated by the wind; and secondly, it soon became worn and injured at the points where it was riveted. It served, however, very well for eighteen months to transmit twelve horse-power to a distance of eighty meters.—The success of the principle was complete, but much remained to be done before the wire rope and the

rubber or leather-lined driving wheel solved all difficulty, and brought the principle to be a practical reality.

The number of applications of this method of transmitting power has increased very rapidly. At the end of 1859, there were but few applications in use. In 1862, there are known to have been about 400, and in 1867 about 800. At the present time there are several thousand in successful operation. In 1864, a terrible explosion destroyed almost all of the great powder mill at Ockhta, situated about six miles from St. Petersburg. The whole establishment was rebuilt. After studying many combinations, an artillery officer proposed to profit by the resources which the telodynamic cables offered to engineers, and thus to realize the only combination which could prove successful in a powder-mill; namely, a great distance between the buildings, so that the explosion of one should not entail the ruin of the rest. The new establishment, which went into operation in 1867, is composed of thirty-four different workshops or laboratories, to which motive power is transmitted by means of wire ropes driven by three turbines, thus distributing a total of 274 horse-power along a line nearly a mile in length.

The largest transmission is that employed to utilize the falls of the Rhine, near Schaffhausen, in Switzerland. Advantage was taken of the rapids at one side, to put in a number of turbines, aggregating in all 600 horse-power. Since the steep rocky banks forbade the erection of any factories in the immediate vicinity, the entire power was transferred diagonally across the stream to the town, about a mile further down, and there distributed, certain rocks in the water being made use of to set up the required intermediate stations. In the industries we frequently meet with a similar case. Many valuable sites for water-power are lying idle in this country, for want of building room in their immediate vicinity. New England especially abounds with them. Coal being so dear there, their value is all the greater. Since the water can only be led down hill in certain directions, the cost of a canal or flume would in most cases come too high, and so the power remains unimproved. By ropes, however, we can convey the power of a turbine or water-wheel in any direction, both up stream and down stream; up an ascent of 1 in 8 or 10, or down a moderate slope as well. The power need not be confined to one factory, but may be distributed among a dozen, if necessary, located so as to suit their particular business, and not to suit the oftentimes inconvenient location of a canal.

Thus, by means of the transmission of power by wire ropes, we may utilize all this power that is now being wasted, and devote it to a useful purpose.

HOW TO DRAIN A HOUSE.*

By T. MELLARD READE, C. E.

From "The Builder."

THE subject of my paper is not one to excite the imagination, to give scope to lofty ideas, or to raise emotions of the sublime and beautiful. It is essentially of the earth, earthy. To what extent the great masters of our art had to condescend to consider so humble a subject as house drainage, I have not seen recorded in our text-books. Whether this has had anything to do with the grudging attention usually paid to house drainage by the profession I am not aware. Admittedly it is an unentertaining subject and not one calculated to excite the interest of the artistic mind, fed on the exciting but not very nourishing food of the competition perspective.

The architect, as a rule, not taking any special interest in this class of work, usually, as regards the carrying out of his plans, relegates it largely to the clerk of works, or, if there be none, leaves it in the hands of the bricklayer, who hands it over to a laborer, and as clerks

* Read before the Liverpool Architectural Society, November 29th, 1876.

of works are not always paragons of knowledge and accuracy, and bricklayers are not the most scientific of men,—even though as honest as the one to whom Professor Huxley would entrust the planning of a college in preference to engaging the services of an "eminent architect,"—the drainage works are, to speak in the mildest terms, frequently unsatisfactory.

But, as is often the case, that which at first repels us becomes interesting on closer study, and with the view of promoting a more exact and scientific way of carrying out the drainage of a house, I have ventured to submit to your consideration the following practical observations on "How to Drain a House."

With the introduction of the complex arrangements of the modern house,—complex, at all events, as compared with that which satisfied our forefathers,—but more especially as the natural complement of an abundant water supply delivered to each individual house, the modern system of sewerage became a necessity. It is not my present purpose to deal with the "sewer,"—that is, the duct in the street provided by the sanitary authority which usually, and especially in towns, performs the separate functions of a drain for surface-water and a duct for "sewage." For my present purpose I assume, in my first example, that it exists, and, in my second example, that our supposed building is away from the modern luxury of a sewerage system, in which the disposal of the sewage itself becomes one of the main considerations, and is of primary importance.

Before treating of the general principles to be followed in house-drainage, I may remark that in the selection of the materials of our drains there is not now much choice. The use of glazed fire-clay or earthenware pipes is almost universal. Cement pipes have been recommended by an eminent authority, but as I have had no experience of them it is not necessary for me to do more than mention them. No one would now propose to use brick or stone culverts, or drains square in section, with sides of brick, and bottom of slate, as were formerly in vogue. Practically, then, our choice of materials is limited, but as usual there are great variations in the quality of the article supplied, not only by different, but by the same manufacturers. What the architect should insist upon is a strong, well-burned, material, accuracy in form, both sectionally and longitudinally, true sockets, and a good smooth glaze. The smaller pipes are especially liable to be twisted longitudinally, and such should be at once rejected. Pipes having a rough interior should not be used, as lumps and blisters in the glaze accumulate material round them and injure the efficiency of the drain.

At the risk of being accused of putting the cart before the horse, I will also explain the practical art of laying drain-pipes and the fall it is necessary to give them before touching upon the general question of how to design house-drainage. I do this because I consider the proper laying of the pipes one of the most important parts of drainage, and the one in which failures most often occur, and without which any system of house-drainage will not perform its functions satisfactorily. The true laying of a pipe is of more importance than its quality. An inferior, rough and crooked pipe may if laid properly under ordinary circumstances be made to perform its work satisfactorily, whereas the best made pipe in the world will only act for a time, and then inefficiently, if laid in those beautiful vertical and horizontal sweeps known as Hogarth's line of beauty, so frequently seen only in their full perfection when a drain is taken up.

The righteous indignation of the bricklayer and his laborers employed in taking it up, against the tradesman who laid it down, is only fully appreciated when, on having to take the drain up a second time, we find these honest men have put in a pipe without a socket, or a square junction, or a junction turned the wrong way, or accidentally omitted to make a joint good, or done or left undone some one of those multitudinous things essential to good workmanship. Truly the architect's bed is one more of thorns than roses.

The next thing to be determined upon is the fall, and I cannot too strongly insist upon the necessity, in all cases, of having the levels first accurately taken and a section made before the drains are

put in. This is an additional trouble, no doubt, but will be amply repaid in the quality of the work. Of course, when the whole of the trenches can be opened at once, this is not always necessary; but it more often happens that the trench has to be filled up as the work proceeds, either from the nature of the ground or the exigencies of the site. The architect should, of course, aim at getting the greatest amount of fall from the sewer to the junction with the branch drains of the house, keeping in view that these should themselves have quicker gradients than the main drain. Without a section it is generally difficult to do this. A fall of 1 in 48, or half an inch to a pipe, is a good one for a main drain; but it sometimes happens that this cannot be obtained. Nay, I have myself had to lay them nearly level; but in such cases special flushing arrangements are absolutely necessary. The usual system pursued by the "honest bricklayer" is to start from the main sewer and lay each pipe to a fall by a straight-edge with a piece of wood planted on one end. The size of this piece is determined by some rule no doubt,—probably the rule of thumb; a rule, I need scarcely say, of very wide and universal application. By means of these implements the drain gradually rises towards the house; but whether it hits the exact level or falls below it, or is a foot or two higher, Providence alone can determine; at all events, I may say it is not so certain to work out right as were the two driftways through Mount Cenis. It not seldom happens that if the workman finds he has made a bungle and got too high, he either carries his drain on a level, or actually dips it the wrong way. And what does the architect do? He sees the end of the pipe at the proper level, and all the rest carefully covered up, and probably assumes that all is right.

There is another internal defect arising from this way of laying pipes; they are laid by the flanges, and the inverts, which are of primary importance, are left to take care of themselves. I have never seen outside of my own practice house-drains laid by their inverts; but I consider this should, where the fall is limited, always be done. It is readily done, but the drain-layer has to be taught, and it is a good deal of trouble to teach him, but not more than, I hope, any architect interested in the perfection of his work would undertake. The method of proceeding is by fixing sight-rails at the two ends of the drain, and sighting a boning-rod with a T-piece at the top, and a bent piece of iron or shoe to fit on to the invert at the bottom. This, of course, usually involves a correct system of levels and bench-marks, with the depths figured on the drawing. The joints should in all cases be made in cement; half Portland cement and half sand is a good proportion; and special care should be taken to scrape out the cement on the inside of the joint, so as to leave as perfect a tube as possible, free from lumps and obstructions. I need scarcely say half-bricks should not be left in the pipes, but I have not unfrequently found them there.

Having now described some of the more important structural details necessary to the efficient action of any system of drainage, I shall next discuss the best system to be adopted.

It is pretty generally admitted that all drains should be on the outside of a house, and in no cases, except through unavoidable necessity, should they be carried through it.

The soil and waste-pipes from water-closets, baths, and lavatories, should also be taken as far as possible outside. I assume, in the first place, that every sink, basin, and bath is trapped inside the house with an S trap, constructed so as to be readily cleaned. If this is not done, draughts of air will come up them into the room, conveying the stench from the organic matters coating the interior surface of the pipe, even though the sewer gases should be carefully excluded by external arrangements such as I shall presently describe. The water-closet is always fitted with an S trap, which should not exceed four inches diameter, though the soil-pipe into which it empties is better larger, and I frequently specify it five inches. I consider the pan-closet objectionable, especially since the compulsory introduction of the two-gallon regulating cistern has increased the difficulty of getting the after-flush to fill the pan. The container is a reservoir coated with filth, hidden by the pan holding the water in the basin. A basin with a trap at the side or back, called a

wash-out basin, is a far better apparatus. If a pan-closet is used, it should always have the container ventilated. Baths and lavatory basins should never have their outlets into the soil-pipe of the closet: this is often done to save expense, and even the trap of the closet is used to trap the waste-pipe from basins and baths; but this is still more objectionable. The soil-pipe of a closet should in all cases be an independent pipe, into which nothing but the soil enters, and it should be carried up above the eaves of the house, full bore; if to the top of a chimney-stack all the better, and it should be, except in those cases where it acts also to take the gutter-water from the roof, fitted with a wind-guard or revolving cowl to prevent down-draughts.

We now come to the drainage proper by which all the separate outflows of waste organic matter are to be carried off and into the main sewer.

In designing a system of house-drainage we must decide, in the first place, whether we keep our rainwater separate. In the case of a house supplied with hard water it is advisable to store the rainwater, and this is best done, as is usual, in an underground brick tank cemented inside, called a terras cistern. It will nearly always be found that there are some down-spouts that, through the levels, cannot be readily connected with this cistern. These should be turned into the drain, which they will help to flush and keep clean. In cases, however, where the sewage has to be disposed of independently of a main sewer, the rainwater is rather a trouble than otherwise, and those pipes unconnected with the rainwater cistern should be turned on to the surface channels or made to flow over a grass plot. The overflow of the terras cisterns should in no case, where it is possible to avoid it, be in any way connected with the drain; if it is we can never be sure of the purity of the water, and I have known instances where the whole of the house has been connected with the sewer through the rainwater cistern; the air-space above the cistern being connected with the space under the floor of the house, the overflow being taken into the sewer and untrapped. Even if trapped we have no security, as the water in the trap dries up before the cistern overflows again. On the other hand, if the overflow be taken into an air-chambered trap supplied with water from another source, there is always the possibility of the trap choking through inattention and the sewage water backing into the tank. The overflow should be taken into an absorbent well, or discharged on the surface of the ground, which, if the levels allow it, is still better.

In some cases the sewage from the baths, basins, and sinks is carried independently into a tank from which it is pumped to be used for garden purposes. The soil alone of the water-closets is taken into the main-sewer. This is an arrangement also suitable for a house supplied with earth-closets, and one I am adopting at the New Truant Schools at Hightown. Where there is a man employed constantly who can look after the tank, and keep it empty, or plenty of labor in the shape of boys to pump it dry every day, the arrangement is a good one, and combined with the earth-closet in such cases, with land on which to use it, the main-sewer can be dispensed with altogether. In all cases where it is possible the sewage should be used before decomposition sets in. In those special instances, and these constitute a large class of cases, where there is no main sewerage, and there is not labor to keep the tank pumped frequently, other methods must be adopted. The ordinary cesspool is an abomination, containing as it does a festering and decomposing mass of filthy matter which is not removed until it attains the consistency of a solid pulp. This is the absorbent well. If such a thing has to be adopted, it should be well ventilated, and the connection of the house-drains with it effectually cut off. I am, however, trying another system, which, if it succeeds, I shall be happy to explain at a future time.

Let me describe the drainage of a large villa as recently carried out by me. The sewage or slop-tank is placed in a convenient position in the kitchen garden, and the levels so arranged that the inlet drain discharges into it above the level of the garden surface. I consider this a matter of great importance, for by doing so I get an overflow on to the surface, and it is impossible for the sew-

age to back up the pipe and seal the end of it to the atmosphere. I have known this purposely done, and indeed have in former times dipped the end of the pipe below the surface of the water with the mistaken view of "trapping it," but find by experience it is an entire mistake, as the first thing to be considered after providing for the flow of the water is to arrange for the circulation of the air. By no other means can we ensure the drains being kept sweet. The tank is constructed of brick in cement, vaulted over with an arch in which is an iron manhole cover; it is in no way an absorbent well, and the whole of the sewage must consequently be pumped out and disposed of on the surface or by the overflow. By such means the organic matters get oxydised in percolating through the pores of the earth, whereas in the case of an absorbent well such oxydization does not take place, but all the surrounding subsoil becomes sewage sodden as the atmosphere is permanently excluded. From the tank a drain is laid on a bank at an inclination of 1 in 80 and 1 in 16, gradually increasing as it approaches the house. This a drain should always do. There is a manhole containing at the bottom one of Pott's air-chambered traps which I will presently describe. This effectually severs the connection between the tank and the house, as all the slop-drains converge at this point. From the tank side of the S trap is carried a four inch ventilating pipe to the upright ventilator, which consists of a five inch cast-iron pipe terminating on a chimney-stack, with a cowl carried up above the chimney-pots. This also acts as a ventilator for the soil drains, as I will presently show. The slops are drawn from three situations, terminating in two cases in Pott's traps, which sever the connection between the house and the drains between it and the manhole. This completes the slop drainage.

The soil-drain commences at the main sewer in the road with a nine inch pipe, at an inclination of 1 in 10, 1 in 53, and 1 in 12. At the point where the branch drains converge is a manhole, and at the bottom is a six inch S trap built up solid in the brickwork. This trap occupies half of the manhole, the other half is an open duct, and as the drain is nine inches on the other side this open duct converges. The bottom of the duct is of glazed brick, and is laid at a greater inclination than the sewer. The manhole is contracted towards the surface, and fitted with a cast-iron manhole cover and a side ventilator. It will thus be seen that all communication between the main sewer and the house is effectually prevented. Further on the drain diminishes to six inches, and is connected with the vertical ventilating pipe by a four inch branch; it is then carried on to the water closets, as shown. The soil-pipe is carried up as a ventilator, and terminated with a cowl. Along the course of the drain are apertures for putting the garden-hose in for flushing it above the flushing-tank. There is a flushing-tank supplied with water from the main. It is of brick in cement, and is fitted with one of Doulton's valves. Occasionally the tank is filled with water by a tap from the main, the valve drawn up, and the hydraulic force developed is sufficient to clean out the drain. Had there been a convenient spot for it I should have placed the flushing-tank at the head of the drain. I have used these tanks for a good many years, and with most beneficial effect. As a rule, the amount of water running down a house-drain is insufficient to keep it clean, and frequently have I had to take up drains filled up solid with deposit, which, if they had been capable of being flushed out in the way named, might have been kept perfectly clear. By the combination of manholes and traps in every case I get a through current of air in the main drains.

The inlet is open, and the outlet is in one of the two ventilating shafts. This keeps the drain perfectly sweet. The house is entirely isolated from external influence, and the drains instead of being filled with fœcal matters are kept clean and free. The division of the slops and soil where there is main sewerage, is, of course, not by any means absolutely necessary, but is a refinement I should only recommend in a large house, where the slops are valuable in the garden, and where there is labor to dispose of them. The slops might be taken into the main sewer, the house being isolated therefrom just the same.

The manhole, with its contained trap,

is a novel feature of great utility; by it, the drain can be inspected, and if the trap should get accidentally choked, such a calamity is found out and obviated at once; whereas, otherwise, the first notice of it in many cases may be the backing up of the sewage into the foundations. It is an inspection place, which no system of drainage should be without, as, otherwise, it is impossible to say whether the drains are working properly or not.

Formerly, trapping a drain meant bottling up the gases in it, now it is recognized that no system of trapping is perfect without ventilation combined with it. There are many patterns of traps for effecting this, besides those I have used here, but I have not space to describe them.

To conclude, there is no part of the house which more wants supervision than the drainage, and no part that is more difficult to supervise. Speaking to architects, I may say that five per cent. commission will not pay for the necessary labor. I never expect it to do so; but, as it is part of the whole, I think, it being so necessary to health, that attention should be paid to it all the same. I picture to myself the happy time when $7\frac{1}{2}$ per cent. commission will enable an architect, without robbing himself, to do full justice to his client; but, I fear, at present, it is only a pleasing fiction of the imagination not soon to be realized. Admittedly the system of contract competition now in vogue, and its consequent demands on one's time, through having to specify every nail and screw, to foresee everything, and to provide for everything, is a great and increasing tax upon the mental resources of architects. Perhaps my little contribution may assist some in this difficult profession; at all events, practical description is of the utmost value to those who desire to learn, and I trust my remarks may be useful to them, if not to those who have grown gray in the service.

FIRE-PROOF CONCRETE.

From "The Architect."

Concrete as a building material may no doubt be said to be in its infancy, whether it is ever to attain to a much more mature condition or not. At all events, it appears that the action of Parliament is now being brought to the aid of an investigation of its properties; and a certain document has been placed in the hands of the members of the Institute of Architects whereby it seems to be expected there will be some sort of information obtained from the architectural profession upon which Parliament may proceed. Lord Elcho, we are thus told, has suggested to the Institute the appointment of a Committee "with the view of reporting on the subject of 'Concrete as a Fire-resisting Material' to a Select Committee of the House of Commons." The Council has therefore nominated the desired Committee (although no intimation is given as to who are the members appointed); and the document we have alluded to as being in the hands of the members at large, consists of a series of questions, in answer to which those who have anything to say upon the subject may say it. The questions turn upon the mode of composition followed, the proved strength of the material so made, and the effect of fire upon it; there being a supplementary inquiry at the end which refers to one's experience of concrete otherwise than as merely resisting fire. Whatever may be the purpose of Lord Elcho, it is manifest enough that all this opens up to such architects, and no doubt other persons, as may take an interest in the subject, a wide field of practical building science.

There are two points upon which at the outset some little embarrassment may be felt. What is precisely meant by concrete? And what is precisely meant by fire? We may probably take it that the form of the material intended to be referred to in the questions is the more or less common-place building concrete at present in use, and that the degree of

combustion to be taken into consideration is the supreme force of a great warehouse fire; and, so far as these limits go, we see a probability of the Institute Committee being able to effect something which shall be satisfactory in the way of accomplishing at least a clearer understanding than at present exists of the capabilities of the material; but still it must not be forgotten that there are now a good many diverse kinds and qualities of this concrete, and that their respective values against fire range from very high pretensions down to nothing at all; and when we also take into account that the material and its professed attributes are at the present moment the subject of rival advertisements and repeated patents which cannot possibly be reconciled to each other, we must at least be not surprised if the Committee should find itself not a little embarrassed in the end with the wealth of information, more specious than ingenuous, which will be poured in upon it. We had been inclined for a moment to ask why the names of the gentlemen who form this Committee of the Institute have not been announced; but we cannot help reflecting that, unless those members are willing to be personally assailed with circulars and calls from pushing tradesmen to a degree which may be more than inconvenient, perhaps their names are best kept in the dark.

It is a remarkable fact that the first prize-medal ever bestowed by the Royal Institute of British Architects was given for an essay on the subject of concrete. This was in 1835; and Mr. George Godwin was the winner of the honor. How far the subject has progressed since then, both in scientific intricacy and in public importance, some may find it hard to understand; whilst others may only wonder how it happens that, after forty years, we should still have settled so little about it.

At the base of the general question of the use of concrete as a "fire-resisting material" (this, by the way, is a new phrase, and a very good one, which was brought forward by the officials of the Metropolitan Board in their last—unsuccessful—Building-Act Bill) there may be said to lie the striking but quite intelligible proposition of Captain Shaw, that common plastering is one of the very best preservatives of what it may cover from the effect of the heat of a fire. Iron, whether cast or malleable, wherever it is exposed, is virtually helpless. Stone cracks to pieces. Timber of course is fuel. Brick, or in fact any other material that has passed through intense heat in its manufacture, is necessarily fire-proof to the last, except when its comparative thickness is unequal to the mechanical shocks produced by the conflagration. If, therefore, we can find a material which shall be of the nature of plastering superficially, which shall enable us to dispense with exposed iron, which shall be a substitute for stone, which shall do away with timber, and which (although it has not passed through the process of burning in manufacture) shall be substantially as good as brick-work, and as effectually fire-proof if only thick enough, it is very natural that we should look with hope to this material, as one which seems obviously to be capable of being brought to bear upon the task of fire-resistance to any degree and in any form that the conditions of building construction may incidentally require.

There are two typical and principal classes of serious fires in London and other similarly built large towns throughout the country; first, the burning of a small dwelling-house, and secondly, that of a large warehouse. The first involves, so to speak, more danger to life than to property; the house becomes suddenly filled in the dead of night with thick smoke and flame from burning timber-work and furniture, and, unless the fire-escape comes speedily to the rescue, some of the sleepers are suffocated. In the other instance, the circumstances and consequences are altogether different. Some vast depository of inflammable mercantile goods is found to have taken fire; the conflagration spreads rapidly and cannot be subdued because of its mere bulk; and it rages perhaps for days, in spite of all endeavors, until everything within the walls that is capable of being consumed is so destroyed. In the former case, when the timber roof has fallen in, and the floors, likewise of timber, have been broken and burnt through, the thin brick walls are left standing entire, and generally not much the worse. In the other case, a

mass of combustible stores fall to the lowest level of the interior, where it continues to burn until exhausted; and the brick walls, even if more substantial than usual, are frequently twisted from their perpendicular and overthrown, while the iron construction is completely disorganized, the cast iron being broken in pieces and the malleable iron curled about like ribbons.

The use of concrete in both of these cases, looked at in the character of a fire-resisting material, seems to involve very much the same considerations. In the common dwelling-house, if the incombustibility of the interior is aimed at, the only difficulty is how to construct floors and roof, partitions and staircase, without sacrificing this incombustibility. In the great warehouse the problem is the same, and, in its degree, the same difficulty has to be dealt with and no other.

Whether the substitution of concrete for brickwork in the mere walling is to be included at all in the inquiry may be doubted. Again, there are considerations of economy that enter into the question, as regards ordinary houses, which in fact are of so much importance in practice that it becomes impossible to hope that anything approximating to incombustibility can ever be introduced into the common run of our dwellings. It is the interior of warehouses, therefore, to which we may virtually confine our attention.

Turning, then, to this subject, we may in the first place remember the following propositions:

It is said at present that nothing can be really relied upon as fire-proof construction except brick walls, brick piers, and brick vaulting; all of which must be, moreover, of such a substance as to correspond with the area of the building. In a depository of this kind, goods, of whatever nature, may, in a certain sense, be stored without fear. The interior is of course subdivided into limited sections which do not intercommunicate, and all that has to be considered, therefore, is what will happen to any one of these sections in the event of fire breaking out within it amongst goods of a given nature. The answer then becomes obviously matter of detail, and it is quite easy to understand that the combustion of oil itself, and indeed explosive oil, may be made to confine and harmlessly expend itself strictly within the limits of its own section, and that even the flame bursting from the windows shall find no admission to other portions of the building. As for the interior of the burning section, the whole would be brick; and, so long as it is built substantial enough, it would be perfectly fire-proof as an oven. As for doors, the primary idea is that iron is sufficient, provided the doors be double, one on each face of the wall. The question of staircases presents little if any difficulty.

Now if concrete is to be applied to this case, the conclusions to be suggested seem to be the following: So far as the brick walls go, it is not easy to see how they can be improved upon. Partitions also may continue to be of brick. In respect of stairs it is very likely that terra cotta may be considered preferable to everything else. Internal doors, however, seem already to be found to be better of concrete than of iron; although it is certainly difficult to get over the fact that they cannot after all be made without iron framework. But the floors and the roof still constitute the great difficulty; and this is simply because they must necessarily be supported at short intervals. Iron pillars and iron girders are not to be thought of; even if cased in armor of concrete or whatever else, it would be impossible at present to believe in them. Brick piers probably furnish the most truly scientific way of meeting their part of the case; and in a warehouse, where mere lightness of appearance would be but an affectation, it is doubtful whether they can ever be improved upon, especially if Staffordshire brick, for instance, be used, purpose-made. For the floors supported by such pillars, probably concrete, if made of the best materials, might be enough without any aid from iron; but, if iron cannot possibly be dispensed with, let it take the form of a diffused reticulation, and certainly not that of a series of joists, and so it may, by the exercise of ingenuity, be made capable of protection. Roofs, again, if regarded as floors, would be only a repetition of the same construction; and an external covering from the weather, composed of even timber-

work and slating, need scarcely be objected to. We have said enough, however, for our present purpose, which is to show that the task undertaken by the Council of the Institute is not to be disposed of easily; and we will only add the hope that the profession, in answering the appeal, as we may call it, of Parliament, will endeavour to do credit to its scientific character.

ON THE MANUFACTURE AND DURABILITY OF THE STEEL-HEADED RAILS ADOPTED ON THE BAVARIAN STATE RAILWAYS.

By ADOLF GRAU.

From "Organ für die Fortschritte des Eisenbahnwesens."

The suitability of Bessemer steel for the manufacture of rails was investigated at the Conference of German Railway Engineers, held at Düsseldorf, in September 1874, the conclusion being that, although in most respects admirably adapted for the purpose, no method had yet been devised for counteracting the tendency of these rails to occasional sudden rupture.

After referring to a treatise by Herr Windscheid, describing the results obtained with the steel rails laid on the Coln-Minden railway in 1867, which were generally satisfactory, and also to an article by A. Petzholdt and H. von Waldegg on the subject of steel-headed rails, as manufactured at the Queen Mary Works, Zwickau, since the year 1867, and laid on the Saxon State railways, the Author proceeds to describe his own experience of steel-headed or compound rails manufactured under his superintendence since the autumn of 1868, at the then newly-erected Maximilian Works at Haidhof, the first of which were laid on the Munchen, Augsburg and Bamberg railway in 1869.

During the year 1874, blast furnaces, erected at Kamsdorf, Thuringia, in connection with the Maximilian works, were blown in, and from thence the supply of crude iron for Bessemer steel is obtained; before that time the iron used for the purpose was either of best English hæmatite pig, or that of the Osnabrück, Niederschelden, and Styrian districts, the process of conversion being partially regulated by the spectroscope.

The rail-pile, after heating, is hammered, reheated, rolled into the finished rail, and sawn to the desired length. From twelve to twenty of the rail-ends, thus cut off, are each day tested by doubling under the steam hammer (seldom effected without signs of fracture); others, again, are subjected to the test of a weight of 11 cwt. (10 centners), falling freely through a distance of 9.84 feet, the points of support of the rail under trial being 3.28 feet apart, the limit of depression for that distance being fixed at 5.9 inches; and in all cases this has been satisfactorily borne.

Bars were placed on each side of the steel head-plate with the design of preventing the burning of the former; but this arrangement was, in 1871, discontinued, it being found that, in the process of rolling, these protection plates generally were extended too far up the sides of the rail-head, and when subjected to traffic separated from and were stripped off the steel portion, although no accident occurred through this.

The rails, which were rolled from this form of pile in the years 1869-70, failed to the extent of from 1 to 2 per cent. of the total production. In 1871, however, there were only a few instances, and since then the rails have been totally exempt. Where it occurred the separation of the steel from the iron proceeded so gradually as to render the withdrawal of the rails unnecessary until six months after the first signs of weakness had appeared. The rails manufactured in 1871 were, however, subject to another form of failure, which first presented itself in the shape of dark-colored streaks, extending from the rail-end along the head, developing into cracks of from 3 to 6.5

feet in length, followed by partial breaking up of the surface. This was attributed to the unsuitable quality of the steel, and might probably have been avoided by a more careful conduct of the conversion process and testing of the surplus rail-ends.

The absolute ruptures were few. The Author is aware of only nine instances; in each case they took place at the fish-bolt holes, which are of rather large dimensions, viz., 1.46 inch by 0.98 inch, the outer hole being 1.12 inch from the rail-end.

In 1871 the form of the steel head-plate was modified, it being rolled with a projection on the under surface, to insure better combination with the iron portion of the rail, and this form has been adhered to up to the present time.

During the last two years rolls have been erected for the special purpose of separating the steel and iron in surplus rail-ends, the steel being returned to the crucible, whilst the web is cut from the foot, and both are utilized in making up the new piles.

As regards resistance to wear, the head of the compound differs slightly from that of the steel rail, in that the former must be composed of metal of a softer and more weldable character (to insure combination with iron) than is necessary for rails made entirely of steel.

The following table shows the amount of wear of the compound rails, measured at their mid-length:

Year of Manufacture.	Amount of wear. Inch	Millimeter.
1869	0.039	or 1.0
1870	0.047	or 1.2
1871	0.019	or 0.5
1872	0.019	or 0.5

The experimental steel rails laid on the Cöln-Minden railway, after being subjected to ten years' traffic, show an amount of wear of from 0.08 inch to 0.12 inch.

The quantity of steel-headed rails originally delivered to, and the proportion of the same requiring renewal on the Bavarian State railways, including all the cases of failure already described, is shown in the following table:

(*See Table on next column.*)

	Original delivery. Tons.	Renewals. Tons.	Percentage.
1869	1,393	124	9.00
1870	1,797	61	3.40
1871	2,807	141	5.00
1872	4,802	1	0.03
1873	3,917	..	..
Total..	14.716	327	2.23

If the first delivery of rails in 1869 be omitted from consideration in the above table, there will remain 13,324 tons delivered as against 203 tons, or only 1.5 per cent, of renewals.

Similar steel-headed rails were also laid on the East Bavarian railway, in the year 1869, at places where the gradients are 1 in 100, and the curves of 14½ to 26 chains radius, the percentage of renewals up to the end of the year 1873 being as follows:

1869	0 60 per cent.
1870	0.00 "
1871	2.65 "
1872	0.00 "

It should be remarked that the rails for the East Bavarian railway were not made until after those of the same period, 1869, had been completed for the State railway, the experience gained in the meantime accounting for the great difference in the percentage of renewals, viz., 0.6 as against 9.0 per cent.; and amongst the causes of failure there were only three cases of rupture, viz., two through the fish-bolt holes, and one at a distance of three feet from the rail-end, the remaining defects comprising longitudinal splitting, &c.

If the above results are considered unfavorable, it should be remembered that most of the Bavarian railways are single lines, that a considerable length of the State railways is laid on stone-blocks, and with heavy gradients and sharp curves; also that the traffic on the main lines consists principally of heavy goods trains, as, for instance, on the single line from Nurnberg to Wurzburg, which forms part of the through route between Cologne and Vienna, and where there is a daily traffic of 144 engines and 1,360 wagon-axles. Here, since 1871, have been laid the steel-headed rails, at the most trying places, viz., on gradients of 1 in 100; and up to the present time not a single rail has been renewed. The number and date of laying are:

1871	556	rails.
1872	1,906	"
1873	1,518	"
Total	3 980	"

The steel-headed rails for the Bavarian State railways weigh 75.3 lbs. per yard, and are rolled in lengths of 19.7 feet, and 20.4 feet.

Where the failures have occurred it has been generally at those parts of the line where blocks are in use. Where sleepers are laid the renewals have been inconsiderable.

EFFECTS OF STRESS ON MAGNETIZATION OF STEEL AND IRON.

By Prof. Sir W. THOMSON, LL. D., F. R. S.

Proceedings of the Royal Society.

Weber's method, by aid of electromagnetic induction and a "ballistic galvanometer" to measure it, which has been practised with so much success by Thalén, Roland, and others, has been used in the investigation of which the results are at present communicated; but partial trials have been made by the direct magnetometric method (deflections of a needle), and this method is kept in view for testing slow changes of magnetization which the electromagnetic method fails to detect.

The metals experimented on have been steel pianoforte-wire, of the kind used for deep-sea soundings by the American Navy and British cable-ships; and soft-iron wires of about the same gauge, but of several different qualities.

I. *Steel.*

The steel wire weighs about 14½ lbs. per nautical mile and bears 230 lbs. Weights of from 28 lbs. to 112 lbs. were hung on it and taken off, and results described shortly as follows were found:

(1) The magnetization is diminished by hanging on weights, and increased by taking the weights off, when the magnetizing current is kept flowing.

(2) The residual magnetism remaining after the current is stopped is also diminished by hanging on the weights, and increased by taking them off.

(3) The absolute amount of the difference of magnetization produced by putting on and taking off weights is greater with the mere residual magnetism when the current is stopped than with the whole magnetism when the magnetizing current is kept flowing.

(4) The change of magnetization produced by making the magnetizing current always in one direction and stopping it is greater with the weights on than off.

(5) After the magnetizing current has been made in either direction and stopped, the effect of making it in the reverse direction is less with the weights on than off.

(6) The difference announced in (5) is a much greater difference than that in the opposite direction between the effects of stopping the current with weights on and weights off, announced in (4).

(7) When the current is suddenly reversed, the magnetic effect is less with the weights on than with the weights off.

II. *Soft-Iron Wires.*

Wires of about the same gauge as the steel were used, but, except one of them, bore only about 28 lbs. instead of 230. All of three or four kinds tried agreed with the steel in (1).

The first tried behaved (except a seeming anomaly, hitherto unexplained) in the reverse manner to steel in respect to (2), (4), (5), and (6); it agreed with the steel in respect to (7). Another iron wire*, which, though called "soft," was much less soft than the first, agreed with steel in respect to (1) and (2), but [differing from steel in respect to (3)] showed greater effects of weights on and off when the magnetizing current was flowing than when it was stopped.

Other soft-iron wires which were very

* It was tested magnetically with weights up to 56 lbs., and broke, unfairly however, when 63 lbs. were hung on.

soft, softer even than the first, agreed with all the steel and iron wires in respect to (1), but gave results when tested for (2), which proved an exceedingly transient character of the residual magnetism, and were otherwise seemingly anomalous.

The investigation is being continued with special arrangements to find the explanation of these apparent anomalies, and with the further object of ascertaining in absolute measure the amounts of all the proved effects at different temperatures up to 100° Cent.

THE EVAPORATIVE PERFORMANCE OF STEAM BOILERS.

By D. KINNEAR CLARK, M. Inst. C. E.

Transactions of the Institution of Civil Engineers.

The Author, in 1852, deduced, from a large number of experiments and observations made by himself and by others on locomotive-boilers using coke, that, assuming throughout a constant efficiency of the fuel, or proportion of water evaporated to the fuel, the evaporative performance of a locomotive-boiler, or the quantity of water which it was capable of evaporating per hour, *decreases* directly as the grate-area is increased: that is to say, the larger the grate the smaller is the evaporation of water, at the same rate of efficiency of fuel, even with the same heating surface. 2d, That the evaporative performance *increases* directly as the square of the heating surface, with the same area of grate, and efficiency of fuel. 3d, The necessary heating surface *increases* directly as the square root of the performance; that is to say, for example, for four times the performance of water evaporated, with the same efficiency, twice the heating surface only is required. 4th, The necessary heating surface *increases* directly as the square root of the grate, with the same efficiency: that is to say, for instance, if the grate be enlarged to four times its first area, twice the heating surface would be required for the same evaporative performance, with the same efficiency of fuel.

Let W be the quantity of water evaporated per hour, and C the weight of coke consumed per hour, W and C varying so as to preserve a constant ratio to each other; let h = the heating surface, and g = the area of grate in square feet; then

$$W = m\frac{h^2}{g}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

in which m is a constant. When the water, W, is expressed in cubic feet, and nine lbs. of water are evaporated per lb. of fuel, the value of m, deduced from the results of forty experiments, was .00222; and

$$W = .00222\frac{h^2}{g}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Reducing the standard of one square foot of grate, let w and c be the weights of the coal and the water respectively per square foot of grate, in constant ratio to each other; then, dividing the above formulæ respectively by g,

$$w = m\left(\frac{h}{g}\right)^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and $$w \text{ (cubic feet)} = .00222\left(\frac{h}{g}\right)^2. \quad (4)$$

showing that, when the ratio of the water to the fuel, or the efficiency of the fuel, is constant, the performance of the boiler per square foot of grate increases as the square of the ratio of the heating surface to the grate-area; or, in brief, as the square of the surface-ratio.

The following table of examples, extracted from "Railway Machinery," shows how close the evaporation proceeded according to the square of the surface-ratio, when 9 lbs. of water, at the ordinary temperatures and pressures, were evaporated per lb. of coke:

(*See Table on following page.*)

It was thus found that, practically, there can never be too much heating surface as regards economical evaporation, but there may by too little; and that, on the contrary, there may be too much grate-area for economical evaporation, but there cannot be too little, so long as the

RELATIVE HEATING SURFACES AND RATES OF CONSUMPTION OF WATER IN LOCOMOTIVE-BOILERS.

Classified Groups of Locomotives.	Surface-ratio.	Consumption of Water per hour per square foot of Grate.	Water per lb. of Coke.	Number of Experiments.
	Ratio.	Cubic feet.	lbs.	
E. & G. Railway.....	52	6.15	9.0	13
C. R. Passenger Engines.....	66	8.0	9.1	17
L. & S. W. Railway.....	72	12.0	8.9	2
Sphynx, A, Hercules.....	90	18.0	8.92	8

required rate of combustion per square foot does not exceed the limits imposed by physical conditions.

EXPERIMENTAL DEDUCTIONS OF M. PAUL HAVREZ, 1874.

That the evaporative performance of similar boilers per unit of grate-area increases with the square of the surface ratio, is confirmed by the deduction by M. Paul Havrez of the following law, from the performances of locomotive boilers: That the quantities of water evaporated by consecutive equal lengths of flue-tubes decrease in geometrical progression, whilst the distances from the commencement of the series increase in arithmetical progression. The point, he adds, at which the law begins to prevail, is that at which the radiation of heat from the fuel ceases, and heat is communicated by conduction alone. One of the experiments, of which the results were investigated by M. Havrez, was made by M. Pétiet, of the Northern Railway of France, who repeated the experiment of Mr. Woods and Mr. Dewrance, and tested the evaporative value of the different parts of a locomotive-boiler, having tubes of a length of twelve feet three inches, divided into five compartments. The first compartment consisted of the fire-box, with three inches of length of the tubes; the four tube sections were 3.02 feet long. Using coke and briquettes as fuel, the average results were as follows:

	Fire-box Section.	1st Tube Section.	2d Tube Section.	3d Tube Section.	4th Tube Section.
Surface.....	60.28 box. 16.15 tubes.				
	76.43	179	179	179	179 square feet.
Water evaporated per sq. ft. per hour with coke.....	24.5	8.72	4.42	2.52	1.68 pounds.
Do. do. with briquettes	36.9	11.44	5.72	3.52	2.31 "

M. Havrez's law of progression is traceable here; and whether it be exact or only approximately true, the rapidly diminishing evaporations are corroborative of the results of previous experiments.

If the successive evaporations be set off as ordinates to a base-line representing the advance of the heating surface, and contoured, the area of the figure is a measure of the total evaporation. The area would bulk largely at the first part, whence it would fall rapidly, and taper more slowly towards the end; and it is easily comprehended that such areas of evaporation, for boilers of different total lengths or quantities of surface, would increase practically as the squares of the total surfaces, supposing that the final temperatures of the gases on leaving the boilers were the same.

GENERAL RELATIONS OF GRATE-AREA, HEATING SURFACE, WATER, AND FUEL.

It is well known that, in a given boiler in which the grate and the heating sur-

face are constant—and, of course, also the ratio of the surface to the grate-area—the greater the quantity of fuel consumed per hour, the greater also is the quantity of water evaporated; but that the production of steam increases at a less rate than the combustion: in other words, that the quantity of water evaporated per lb. of fuel is diminished. But it has remained a question—at which rate does this diminution of efficiency take place? The answer is supplied by the fact, generalized from experimental observations on stationary, portable, marine, and locomotive boilers, that the quantity of water evaporated per square foot of grate is expressed by a constant quantity, A, plus a constant multiple, B c, of the fuel consumed per square foot of grate; or by the general formula

$$w = \mathrm{A} + \mathrm{B}\,c \quad . \quad . \quad . \quad . \quad . \quad (5)$$

The sense of this equation is that, though the proportion of the water evaporated per square foot of grate does not keep pace with the fuel consumed, yet that the quantity of water increases by equal increments for equal increments of fuel per square foot of grate.

To co-relate this formula (5), in which the surface-ratio is constant, with the formula (4), in which the evaporative efficiency of fuel is constant, it may suffice for the present to observe that the quantity B c is constant for all surface-ratios, and that the quantity A varies as the square of the surface-ratio. Let the surface ratio $\frac{h}{g} = r$, then $\mathrm{A} = ar^2$, in which a is a constant which is specified for each kind of boiler; and

$$w = ar^2 + \mathrm{B}\,c \quad . \quad . \quad . \quad . \quad . \quad (6)$$

w = the water evaporated in lbs. per square foot of grate per hour;

c = the fuel consumed in lbs. per foot of grate per hour;

$\mathrm{E} = \frac{w}{c}$, the efficiency of the fuel, or the weight of water evaporated per lb. of fuel;

$\mathrm{A} = ar^2$ = a constant, specific for each kind of boiler;

B = a constant multiplier, specific for each kind of boiler;

$r = \frac{h}{g}$ = the ratio of the heating surface to the grate-area; or the surface-ratio;

a = a constant, specific for each kind of boiler.

When the consumption of water and fuel per square foot of grate per hour is given, the value of the required surface-ratio is found from the above formula, for $ar^2 = w - \mathrm{B}\,c$, and

$$r = \sqrt{\frac{w - \mathrm{B}\,c}{a}} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

When the consumption of water per square foot of grate per hour, and the surface-ratio, are given; to find the amount of fuel per square foot of grate per hour required to evaporate the water; $\mathrm{B}\,c = w - ar^2$, and

$$c = \frac{w - ar^2}{\mathrm{B}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

When the efficiency, $\mathrm{E} = \frac{w}{c}$, of the fuel is given—that is, the weight of water evaporated per lb. of fuel—also the surface ratio; to find the fuel that may be consumed per square foot of grate per hour corresponding to that efficiency. As $\frac{w}{c} = \mathrm{E} = \frac{ar^2 + \mathrm{B}\,c}{c} = \mathrm{B} + \frac{ar^2}{c}$; then $ar^2 = c\,(\mathrm{E} - \mathrm{B})$; and

$$c = \frac{ar^2}{\mathrm{E} - \mathrm{B}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

When the efficiency, $\mathrm{E} = \frac{w}{c}$, and the fuel consumed per square foot of grate per hour, are given; to find the surface-ratio required to effect that evaporation. Since $ar^2 = c(\mathrm{E} - \mathrm{B})$, and $r^2 = \frac{c(\mathrm{E} - \mathrm{B})}{a}$,

$$r = \sqrt{\frac{c\,(\mathrm{E} - \mathrm{B})}{a}} \quad . \quad . \quad . \quad . \quad (10)$$

Evaporative Performance of South Lancashire Coal in three Experimental Stationary Boilers at Wigan. 1866–68.

The coal selected for trial was Hindley Yard coal, from Trafford pit, which ranks with the best coals of the district. Three stationary boilers were selected: 1. An ordinary double-flue Lancashire boiler, 7 feet in diameter and 28 feet long; two flue-tubes, 2 feet 7½ inches in

diameter inside, of $\frac{3}{8}$-inch plate. 2. Another Lancashire boiler of the same dimensions, but with tubes of $\frac{5}{16}$-inch steel plate. 3. A Galloway or water-tube boiler, 26 feet long and 6 feet 6 inches in diameter, with two furnace-tubes 2 feet $7\frac{3}{8}$ inches in diameter, opening into an oval flue, 5 feet wide by 2 feet $6\frac{1}{2}$ inches high, containing twenty-four vertical conical water-tubes. These three boilers were set side by side, on side walls, and with two dampers. The flame passed through the flue-tubes, back under the boiler, then along the sides to the chimney. The chimney was 105 feet high above the floor, octagonal, 6 feet 10 inches wide at the base and 5 feet wide at the top, where the sectional area was 21 square feet.

	ft. long.	sq. ft.
Total grate-area in each boiler..	6	31.5
Total grate-area in each boiler..	4	21.0

Heating surface:	Lancashire. sq. ft.	Galloway. sq. ft.
In flue tubes.....	464.34	431.12
In external flues.....	303.08	288.24
Total surface.....	767.42	719.36
Ratio of grate-area, 6 feet long, to heating surface.	1 to 24.4	1 to 22.8
Ratio of grate-area, 4 feet long, to heating surface.	1 to 36.5	1 to 34.3

Circuit, or length of heating surface traversed by the draft from the center of the grate.....	80 feet	74 feet.
Total distance from center of grate to base of chimney.....	117 feet	101 feet.
Height of chimney above level of floor.....	100 feet	
Height of chimney above level of grates.....	96 feet 9 inches.	

The standard fire adopted for trial was 12 inches thick, of round coal, treated on the coking system, with a little air admitted above the grate for a minute or so after charging. The water was evaporated under atmospheric pressure.

The data afforded by these typical boilers are specially useful, as they represent classes of boilers in general use in England. The several experimental results, required for the present purpose, are collected in the annexed table. The first two results are for flash-drafts, in which the side and bottom flues were cut off, and the gases were conducted direct to the chimney after having passed through the fire-tubes. By plotting the coal and the water reduced according to the square of the

WIGAN STATIONARY BOILERS. RELATIONS OF COAL AND WATER.

Varying grate-area and surface-ratio. Calculations for surface ratio 30, by formula (13).

Boiler (without Economizer).	Grate-area.	Surface-ratio.	Coal per square foot of Grate per hour.		Water per square foot of Grate per hour, for surface-ratio, 30.		
			Actual.	Reduced in the ratio of the squares of the surface-ratios for ratio 30.	Reduced in the same ratio.	Calculated from column 5 by formula (13).	Difference by formula.
	Sq. feet.	Ratio.	lbs.	lbs.	lbs.	lbs.	Pr. cent.
Galloway, flue-tubes only.....	31.5	13.70	18.58	89.10	757.3	871.8	+15.0
Lancashire, flue-tubes only....	"	14.74	19.91	82.47	678.8	808.4	+19.0
Galloway, complete	"	22.8	18.30	31.68	322.9	322.9	0.0
Lancashire & Galloway.....	"	23.5	14.00	22.82	230.4	238.2	+ 3.4
Lancashire..... ..	"	24.4	17.26	26.03	271.5	268.8	− 1.0
"	"	"	18.60	28.12	290.2	288.8	− 0.5
"	"	"	19.10	28.87	293.7	296.0	+ 0.8
Lancashire, with water-tubes..	"	25.4	16.71	23.31	251.0	242.8	− 3.3
Galloway.....	21.0	34.3	21.80	16.68	179.6	179.5	0.0
Lancashire & Galloway.....	"	35.5	23.00	16.43	179.2	177.1	− 1.2
Lancashire.....	"	36.5	21.50	14.52	158.0	158.8	+ 0.5
"	"	"	22.70	15.33	165.1	166.6	+ 0.9

surface-ratios, for a uniform ratio of 30, this formula was obtained:*

$$w = 20 + 9.56c \quad . \quad . \quad . \quad . \quad . \quad (13)$$

And, in the general form, for various ratios:

$$w = .0222r^2 + 9.56c \quad . \quad . \quad . \quad (14)$$

By the formula (13), the quantities of water in column 7 of the table were calculated from the reduced coals in column 5.

Comparative Evaporative Performance of Stationary Boilers in France. 1874.

An abstract of the Report on the trials of boilers of three types—the "Fairbairn," as it was called, the Lancashire, and the French or elephant boiler—has already been published in the Proceedings, to which reference is now made for particulars. The proportions and the results, with Ronchamp coal, are treated in the following table. The following special formulæ have been deduced for the three boilers respectively, and for the three collectively :†

"Fairbairn" $w = .01143r^2 + 7.7c$ . . (17)
Lancashire $w = .01126r^2 + 8.0c$ . . (18)
French $w = .01126r^2 + 8.0c$ . . (19)
All the boilers $w = .0111r^2 + 7.82c$. (20)

It is seen that the same formula applies to the Lancashire and the French boilers, and that, therefore, the reporters of the trials were justified in asserting that these boilers were equally efficient. The comparatively inferior quantity evaporated in the first trial in the table, resulted probably from an excessively large surplus of air admitted into the furnace. The total quantity of air, in that instance, amounted to 261 cubic feet per lb. of coal.

Evaporative Performance of Locomotive-Boilers.

The Author has collected from various trustworthy sources, the results of the performance of locomotive-boilers of the earliest as well as the most recent designs. Boilers of nearly every size and variety that have been used in England are represented in the tables. The areas of grate vary from 6 to 24 square feet, the heating surfaces from 40 to 2,000 square feet, and the ratios of surface to grate from 40 to 1, to 100 to 1. The fuel was coke, except in a few instances of boilers designed for burning coal, in which coal was used.

These experimental trials have been conducted under various conditions. There is, nevertheless, a remarkable

Stationary Boilers in France. Relations of Coal and Water.

Calculations of evaporative performance for surface-ratio 30; Ronchamp coal.

Boilers.	Grate-area.	Surface-ratio.	Coal per square foot of Grate per hour.		Water per square foot of Grate per hour for surface-ratio 30.		
			Actual.	Reduced in the ratio of the square of the surface-ratios for ratio 30.	Reduced in the same ratio.	Calculated from column 5 by formulæ (17), (18), (19).	Difference by formula.
	Sq. feet.	Ratio.	lbs.	lbs.	lbs.	lbs.	Per cent.
"Fairbairn"	20.5	49.5	10.70	3.93	34.8	40.70	+17.0
"	"	"	18.53	6.81	62.7	63.30	+ 0.9
Lancashire.	"	29.8	10.41	10.55	94.1	92.50	− 1.7
" .	"	"	19.15	19.41	165.0	161.80	− 1.9
" .	"	"	19.50	19.76	166.8	164.50	− 1.4
French.....	20.1	30.3	11.36	11.14	95.5	9.71	+ 1.7
"	"	"	19.87	19.48	165.4	162.30	− 1.9
"	"	"	20.57	20.16	166.6	167.60	+ 0.6

* Some experiments with a marine boiler at Newcastle gave

$$w = 25 + 9.71c \quad . \quad . \quad . \quad . \quad (11)$$
$$w = .02156r^2 + 9.71c \quad . \quad . \quad (12)$$

Details omitted here.

† Formulas 15 and 16 omitted above were deduced from a trial of English coals at Wigan. They are :

$$w = 25 + 10.75c \quad . \quad . \quad . \quad . \quad (15)$$
$$w = .91r^2 + 10.75c \quad . \quad . \quad . \quad (16)$$

degree of harmony amongst them; for, when plotted, they are seen, with a few exceptions of early date, to follow the laws of evaporative performance already enunciated. Even the performance of the boiler of the primitive Killingworth engine, when the evaporative efficiency is increased by one-half to represent the value of coke compared with coal as imperfectly burned in that boiler, ranges as well as should have been expected with those of other locomotives; in fact, the improved Killingworth boiler exhibits a performance above the average.

Using good coke as fuel, the evaporative performance of locomotive-boilers, in which the flue-tubes are spaced sufficiently apart to admit of a free circulation of water around them, is substantially embraced by the following formula, when the surface-ratio is 75, which is a good practical ratio:

$$w = 100 + 7.94c \text{ (coke)} \quad . \quad . \quad (21)$$

For any given surface-ratio, the general formula is

$$w = .0178r^2 + 7.94c \text{ (coke)} \quad . \quad (22)$$

Using good coal as fuel—Griff, Staveley, Hartley's, and coking coal from Newcastle—the formulæ for the coal-burning locomotive-boilers of the South-Eastern and London and South-Western Railways are:

	S. E. Ry.	L. & S. W. Ry.
For surface-ratio 75	$w = 50 + 9.6c$	$w + 50 + 9.82c$. (23)
For any surface-ratio	$w = .009r^2 + 9.6c$	$w = .009r^2 + 9.82c$ (24)

EVAPORATIVE PERFORMANCE OF PORTABLE STEAM-ENGINE BOILERS. 1872.

The results of the excellently-conducted trials of portable steam-engines exhibited at the Show of the Royal Agricultural Society at Cardiff, in 1872, were fully reported by the Judges, Mr. F. J. Bramwell and Mr. Menelaus. To this valuable Report, with the tables appended to it, prepared by the Consulting Engineers, Messrs. Eastons and Anderson, the Author is indebted for the data with which he has formed the following Table:

PORTABLE STEAM ENGINE BOILERS. PROPORTIONS AND RESULTS OF EVAPORATIVE PERFORMANCE, 1872.

(From the Report of the Judges, Royal Agricultural Society's Show, Cardiff.)

Fuel: Llangennech (Welsh) Coal.

No.	Constructors.	Area of Fire-grate.		Heating Surface (Tubes measured on outside).	Ratio of Heat'g Surface to Trial Fire-grate.	Coal consumed per square foot of Grate per hour	Equivalent Water evaporated from and at 212° Fahr. per square foot of Grate per hour.		Equivalent Water evaporated per lb. of Coal.
		Normal.	As reduced for Trial.						
		Sq. ft.	Sq. ft.	Sq. feet.	Ratio.	lbs.	lbs.	Cub. ft.	lbs.
1	Marshall, Sons & Co...	4.4	3.0	283.5	94.5	15.7	161	2.58	10.23
2	Clayton & Shuttleworth	5.3	3.2	220.0	69	12.8	151	2.42	11.83
	"	"	"	"	"	12.5	148	2.36	11.81
3	Hayes.....	5.1	5.1	170.6	33	14.8	66.5	1.06	4.59
4	Davey, Paxman & Co..	3.75	3.75	168.4	45	10.3	114	1.83	11.02
5	Tuxford & Sons.....	6.13	..	193.0	..	..	..	..	..
6	Brown & May.....	3.2	3.2	159.1	50	9.53	104	1.66	10.89
7	Tasker & Sons...	4.7	4.7	158.0	34	13.0	119	1.91	9.33
8	Reading Iron Works...	7.2	2.37	211.0	89	20.4	214	3.43	10.49
9	Lewin	4.3	1.6	151.6	..	..	..	..	..
10	E. R. & F. Turner.....	3.5	3.5	187.8	54	20.7	204	3.26	9.93
11	Barrows & Stewart....	5.0	5.0	129.8	26	13.6	120	1.93	8.97
12	Ashby, Jeffery & Luke.	5.5	2.0	204.5	102	31.1	319	5.10	9.27

The fuel was Llangennech (Welsh) coal. The average quantity of ash and clinker was, as far as it was observed, about 6 per cent. of the fuel. The boilers were of the ordinary pattern, having a fire-box and multitubular flues; but Messrs. Davey, Paxman, & Co.'s boiler contained, in addition, ten circulating wrought-iron bent water-tubes, 2¼ inches in diameter in the fire-box, rising from the sides to the top.

These boilers are arranged in the

annexed table, in the order of the surface-ratios. The coal and the water per square foot of grate are reduced for the ratio 50 (columns 5, 6), from which has been deduced, by plotting, the formula

$$w=20+8.6c \quad . \quad . \quad . \quad . \quad . \quad (25)$$

For any given surface-ratio the general formula is

$$w=.008r^2+8.6c \quad . \quad . \quad . \quad . \quad (26)$$

The calculated quantities of water (column 7) by formula (25) follow closely the reduced quantities (column 6), except in the first three instances, Nos. 12, 1, and 8, where they are much in excess. In these instances, the excessive reduction of the grate has involved a material departure from the normal disposition of a fire-box, especially for No. 8, in which the grate was reduced to a third of its normal area, and the surface-ratios were driven up to 102, 94.5, and 89; and the first two boilers, Nos. 12 and 1, have the greatest number and the smallest diameters of tubes. The drift of the evidence goes to show that fewer tubes, of larger diameter, do better for the combustion of coal, the circulation of water, and the absorption of heat.

There is another exceptional boiler, No. 3, with a surface-ratio 33, in which the calculated quantity of water is twice as much as the reduced actual quantity. The excess, in this case, is satisfactorily accounted for by causes which were pointed out by the Judges in their reports. They stated that the boiler only did half its duty—an affirmation which is precisely confirmed by the tabulated calculation.

PORTABLE ENGINE BOILERS. RELATIONS OF COAL AND WATER.

Calculations of evaporative performance for surface-ratio 50.

No. of Boiler.	Grate-area as reduced for Trial.	Surface-ratios.	Coal per square foot of Grate per hour.		Water per square foot of Grate per hour for Surface-ratio, 50.		
			Actual.	Reduced in the ratio of the squares of the surface-ratios for ratio 50.	Reduced in the same ratio as for the Coal.	Calculated from column 5 by formula (25).	Difference by formula.
	Square feet.	Ratio.	lbs.	lbs.	lbs.	lbs.	Per cent.
12	2.00	102.0	31.10	7.473	69.28	84.27	+ 21.6
1	3.00	94.5	15.70	4.395	44.96	57.80	+ 28.5
8	2.37	89.0	20.40	5.73	60.11	69.38	+ 15.2
2	3.20	69.0	12.80	6.721	79.51	77.80	− 2.1
"	"	"	12.50	6.564	77.52	76.45	− 1.4
10	3.50	54.0	20.70	17.75	176.20	172.60	− 2.0
6	3.20	50.0	9.53	9.53	103.80	102.00	− 1.7
4	3.75	45.0	10.32	12.72	140.10	129.40	− 7.6
7	4.70	34.0	13.00	28.11	262.30	261.70	− 0.2
3	5.10	33.0	14.80	33.97	155.90	312.10	+100.0
11	5.00	26.0	13.60	50.30	451.10	452.60	+ 0.3

Looking to the evaporating capabilities of the portable-engine boilers in their ordinary condition, with unrestricted grates, it may be useful to show at what rates they are capable of evaporating water from and at 212°, in the ratio of 10 lbs. of water per lb. of coal consumed. For the calculation of these rates, the formula (9), may be employed. It is

$$c=\frac{ar^2}{E-B} \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

The value of **E** is 10; of B is 8.6; and of a is .008; and, by substitution,

$$c=\frac{.008r^2}{10-8.6}\text{; or}$$

$$c=\frac{.008r^2}{1.4} \quad . \quad . \quad . \quad . \quad . \quad (28)$$

By this formula, the value of c, the quantity of coal consumed per square foot of grate per hour, is found, when the surface ratio, r, is given for each boiler.

Thence, multiplying by the grate-area, is found the total quantity of coal per hour; and ten times the coal is the quantity of water. In this way the following table is calculated in which the boilers are placed in the order of their normal surface-ratios. It is seen that No. 2 boiler is capable of evaporating at the given rate of efficiency, 8.15, say 8, cubic feet of water per hour. This is just 1 cubic foot per nominal HP., all the boilers having been designated of 8 H P. No. 11 boiler would only evaporate 3 cubic feet per hour, at the given rate of efficiency; whilst No. 1 is capable, by the calculation, of evaporating 16½ cubic feet per hour. It has already been seen that there is reason, in the design of its tube-surface, for doubting whether No. 1 is capable of so good a performance.

From the last line of the table, it may be assumed that the standard of average practice for portable-engine boilers of 8 nominal HP., is based on the following data, taken in round numbers:

Nominal HP.....	8 HP.
Area of fire-grate.....	5.5 square feet.
Area of heating surface.	220.0 "
Ratio of heating surface to grate-area, or surface-ratio...,.....	40 to 1.
Coal of good quality consumed per hour.....	50 lbs.
Coal of good quality consumed per HP.....	6.25 lbs.
Coal of good quality consumed per square foot of grate, say.....	9 lbs.
Water evaporated, from and at 212° Fahr., per hour, at the rate of 10 lbs. per lb. of coal....	500 lbs. or 8 cub. ft.
" " per HP	62.4 lbs. or 1 "
" " per sq. foot of grate, 91 lbs. say.....	90 lbs. or 1.45

PORTABLE ENGINE BOILERS. CALCULATED EVAPORATIVE PERFORMANCE.
From and at 212° Fahr., at the rate of 10 lbs. of water per lb. of coal.

No. of Boiler.	Surface-ratio.	Grate-area.	Coal consumed per hour.		Total water evaporated per hour.	
			Per square foot of Grate	Total.		
	Ratio.	Sq. feet.	lbs.	lbs.	lbs.	Cubic feet.
2	64	4.40	23.40	102.96	1,029.6	16.50
10	54	3.50	16.66	58.31	583.1	9.34
6	50	3.20	14.30	45.76	457.6	7.33
4	45	3.75	11.57	43.24	432.4	6.93
2	41	5.30	9.60	50.88	508.8	8.15
12	37	5.50	7.82	43.01	430.1	6.89
9	35	4.30	7.00	30.10	301.0	4.82
7	34	4.70	6.60	31.02	310.2	4.97
3	33	5.10	6.22	31.72	317.2	5.08
5	31	6.13	5.50	33.71	337.1	5.40
8	29	7.20	4.23	30.45	304.5	4.88
11	26	5.00	3.86	19.30	193.0	3.09
Averages.....	40	4.84	9.14	44.24	442.4	7.09
To evaporate 8 cubic feet of water per hour	40	5.46	9.14	49.92	499.2	8.0

GENERAL FORMULÆ FOR PRACTICAL USE.

In the French experiments with stationary boilers, the Lancashire and French boilers were, by the formulæ (17 to 20) identical in performance; and the so-called "Fairbairn" boiler was within 3½ per cent. as effective as these. The three forms of boiler may therefore be accepted as equally efficient; and they may be classed with the Wigan boiler, as of equal efficiency, with coal of equal quality, and with equally good management.

The performance of the Howard boiler, as reported, is conformable to the formula for the Wigan boiler; and the Howard boiler is a type of the "sectional" kind of boilers.

The formula for the Wigan boiler is therefore applicable to all stationary boilers other than multitubular, with best coal and good management.

The performances of the Newcastle and Wigan marine boilers are nearly alike. Thus for a surface-ratio 30, the corresponding quantities of water, w, for different rates of coal, c, per square foot of grate per hour, are as follows:

					lbs.
Coal	$c=$	10,	20,	30,	40
Newcastle boiler	$w=$	116.5,	213.6,	310.7,	407.8
Wigan boiler	$w=$	116.5,	224.0,	331.5,	439.0
Differences	$w=$	0.0,	10.4,	20.8,	31.2
					per cent.
Less than Wigan	$w=$	0.0,	4.6,	6.3,	7.1

Halve the differences, and so take a mean of the formulæ; this will give a satisfactory general formula for marine boilers:

Newcastle . $w=.02156r^2+9.71c$
Wigan . . $w=.01r^2+10.75c$

Mean, $w=.016r^2+10.25c$. (29)

For coal-burning locomotive boilers, a mean of the two formulæ adduced, which are nearly identical, will be a satisfactory formula:

S. E. Ry. . . $w=.009r^2+9.6c$
L. & S. W. Ry. $w=.009r^2+9.82c$

Mean $w=.009r^2+9.7c$ . . (30)

The general formulæ which have been deduced are here collected together:

Formulæ for the Relation of Coal and Water consumed in Steam Boilers, per square foot of Grate-area per hour; and the Ratio of the Heating Surface to the Area of the Fire-grate.

Stationary boilers . $w=.0222r^2+9.56c$ (31)
Marine boilers . . $w=.016r^2+10.25c$ (32)
Portable-engine boilers $w=.008r^2+8.6c$. (33)
Locomotive-boilers (coal-burning) . $w=.009r^2+9.7c$. (34)
Locomotive-boilers (coke-burning) . $w=.0178r^2+7.94c$. (35)

LIMITS TO THE APPLICATION OF THE FORMULÆ (31) TO (35).

There are minimum rates of consumption of fuel below to which these formulæ are not applicable. The limit varies for each kind of boiler, and it varies with the surface-ratio. It is imposed by the fact that the maximum evaporative power of fuel is a fixed quantity, and is naturally at that point of the scale where the reduction of the rate of combustion for a given ratio procures the absorption into the boiler of the whole of the heat which is available for evaporation. In the combustion of good coal, the limit of evaporative efficiency may be measured by 12½ lbs. of water from and at 212° Fahr.; and in that of good coke, by 12 lbs. of water from and at 212° Fahr.

To ascertain the minimum rates of combustion of coal for stationary boilers, to which the formula (31) applies: the limit is reached when w becomes equal to $12.5c$; or when $12c=.0222r^2+9.56c$, or $.0222r^2=(12-9.56)\,c=2.94c$. By reduction, $c=\frac{.0222}{2.94}r^2=.00755r^2$. For a given surface-ratio, r, the limiting value of c is found by multiplying the square of the ratio by .00755.

For the other kinds of boiler, the limiting values of c are found in the same way. They are here placed all together:

Stationary boilers,
limiting value of $c=.00755r^2$
Marine boilers,
limiting value of $c=.007r^2$
Portable-engine boiler,
limiting value of $c=.002r^2$
Locomotive-boilers (coal-burning)
limiting value of $c=.00325r^2$
Locomotive-boilers (coke-burning)
limiting value of $c=.0044r^2$

For lower values of c, or consumptions of fuel per square foot of grate per hour, the values of w, the corresponding quantities of water, are simply $12.5c$ for coal, and $12c$ for coke.

The annexed table, contains the limiting values of c for given surface-ratios, r.

The only limit to the application of the formulæ (31) to (35), to ascending values of c, or quantities of fuel per square foot per hour, is the limit of endurance of the fuel itself under the action of the draft—from 100 lbs. to 120 lbs. per square foot per hour, for ordinary hard coal or coke. Beyond this limit, the fuel is liable to be shaken and partly dispersed, unconsumed, by the force of the draft; although coke has been known to withstand the draft of a locomotive, when consumed at the rate of 130 lbs. per square foot per hour.

MINIMUM VALUES OF c, OR MINIMUM QUANTITIES OF FUEL CONSUMED PER SQUARE FOOT OF GRATE PER HOUR, FOR GIVEN SURFACE-RATIOS, TO WHICH THE FORMULAS (31) TO (35) ARE APPLICABLE.

	Surface-ratio.						
	5	10	15	20	30	40	50
	Minimum Consumption of Fuel per square foot of Grate per hour.						
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Stationary	.2	.7	1.7	3.0	6.8	12.1	18.9
Marine	.17	.7	1.6	2.8	6.3	11.2	17.5
Portable	.05	.2	.4	.8	1.8	3.2	5.0
Locomotive (coal-burning)	.1	.3	.7	1.3	2.9	5.2	8.1
Locomotive (coke-burning)	.1	.4	1.0	1.8	4.0	7.0	11.0

	Surface-ratios—*continued*.					
	60	70	75	80	90	100
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Locomotive (coal-burning)	11.7	15.9	18.3	20.8	26.3	32.5
Locomotive (coke-burning)	16.0	21.0	25.0	28.0	36.0	44.0

APPLICATIONS OF THE FORMULÆ FOR THE EVAPORATIVE PERFORMANCE OF STEAM BOILERS.

The following Table contains the relative quantities of fuel consumed and water evaporated, for surface-ratios, and rates of combustion per square foot of grate per hour, within the range of ordinary practice. It is seen that, with the surface-ratios 30 and 50, the boilers are, in the order of evaporative efficiency, as follows:

Surface-ratio 30.

Marine.
Stationary.
Locomotive (coal-burning).
Portable.
Locomotive (coke-burning).

Surface-ratio 50.

Marine.
Stationary.
Locomotive (coal-burning).
Locomotive (coke-burning).
Portable.

Portable-engine boilers are clearly inferior in efficiency to coal-burning locomotive-boilers, and they may be constructed like these with sensible advantage.

(*See Table on following page.*)

EMPLOYMENT OF THE FORMULÆ (31) TO (35) FOR FUELS OF INFERIOR HEATING POWER.

To find the evaporative performance of a given quantity of inferior fuel per square foot of grate per hour: substitute for the given quantity the equivalent quantity of best coal, and find by the formula the water evaporated.

2. To find the quantity of an inferior fuel required for a given evaporative performance per square foot of grate per hour: find, by the formula in its inverted form, on the model of the equation (27), the quantity of best coal required, and substitute for this amount the equivalent quantity of the inferior fuel.

Evaporative Performance of Steam Boilers for Increasing Rates of Combustion and Different Surface-Ratios.

For Best Coal and Best Coke, Surface-ratio 30.

Kind of boiler and fuel.	Water from and at 212° Fahr. per hour.	Fuel per square foot of Grate per hour in lbs.						
		5	10	15	20	30	40	50
					Water.			
Stationary Coal.	Per square foot	lbs. 62.5	lbs. 116	lbs. 163	lbs. 211	lbs. 307	lbs. 402	lbs. 498
Formula (31)	per lb. of coal	12.5	11.56	10.89	10.56	10.23	10.06	9.96
Marine. Coal.	Per square foot	62.5	117	168	219	322	424	527
Formula (32)	Per lb. of coal	12.5	11.69	11.25	10.95	10.69	10.61	10.54
Portable. Coal.	Per square foot	50	93	136	179	265	351	437
Formula (33)	Per lb. of coal	10	9.3	9.01	8.95	8.83	8.77	8.74
Locomotive, Coal-burning	Per square foot	57	105	154	202	299	396	493
Formula (34)	Per lb. of coal	11.4	10.5	10.26	10.10	9.97	9.90	9.86
Locomotive, Coke-burning	Per square foot	56	95	135	175	254	334	413
Formula (35)	Per lb. of coke	11.14	9.54	9.02	8.75	8.47	8.35	8.03
		Surface-ratio 50.						
Stationary. Coal.	Per square foot	62.5	125	187.5	247	342	438	534
Formula (31)	Per lb. of coal	12.5	12.5	12.5	12.33	11.41	10.95	10 67
Marine. Coal.	Per square foot	62.5	125	187.5	245	348	450	552
Formula (32)	Per lb. of coal	12.5	12.5	12.5	12.25	11.58	11.25	11.05
Portable. Coal.	Per square foot	62.5	106	149	192	278	364	450
Formula (33)	Per lb. of coal	12.5	10.6	9.93	9.6	9.27	9.10	9.00
Locomotive, Coal-burning	Per square foot	62.5	120	168	217	314	411	508
Formula (34)	Per lb. of coal	12.5	11.95	11.20	10.85	10.16	10.26	10.15
Locomotive, Coke-burning	Per square foot	60	120	164	203	283	362	442
Formula (35)	Per lb. of coke	12.0	12.0	10.91	10.16	9.42	9.05	8.83
		Surface-ratio 75.						

Kind of boiler and fuel.	Water from and at 212° Fahr. per hour.	Fuel per square foot of Grate per hour in lbs.						
		30	40	50	60	75	90	100
Locomotive, Coal-burning	Per square foot	lbs. 342	lbs. 439	lbs. 536	lbs. 633	lbs. 778	lbs. 927	lbs. 1020
Formula (34)	Per lb. of coal	11.39	10.97	10.71	10.65	10.37	10.26	10.20
Locomotive, Coke-burning	Per square foot	338	418	497	576	695	815	894
Formula (35)	Per lb. of coke	11.27	10.44	9.94	9.61	9.26	9.05	8.94

NOTE.—In applying these rules, a heating power represented by an evaporation of 16 lbs. of water from and at 212° Fahr. may be taken as the standard for best coals, such as were employed in the trial of the Newcastle and Wigan boilers.

HEATING POWERS OF FUELS.

No.	Fuel.			Heating Power of 1 lb. of Fuel.	
				Units of Heat.	Water evaporated per lb. of Fuel from and at 212° Fahr.
				Units.	lbs.
1	Warlich's fuel			16,495	17.07
		Units.	lbs.		
	Coal: Ebbw Vale, 1848	16,221	16.79		
	Powell's Duffryn, 1848	15,715	16.25		
	Llangennech, 1848–71	14,765	15.28		
2	Average (best Welsh)	15,567	16.11	15,567	16.11
3	Haswell Wallsend (Newcastle)			15,502	16.04
4	British Coals, Average			14,123	14.63
5	Coke			13,550	14.02
6	Lignite, perfect			11,678	12.10
7	Asphalt			16,655	17.24
8	Wood, perfectly dry			7,792	8.07
9	Wood, 25 per cent. moisture			5,565	5.80
10	Wood-charcoal, dry			12,696	13.13
11	Peat, perfectly dry			9,951	10.30
12	Peat, 25 per cent. moisture			7,156	7.41
13	Peat-charcoal, 85 per cent. carbon, dry			12,325	12.76
14	Tan, perfectly dry, 15 per cent. ash			6,100	6.31
15	Tan, 30 per cent. moisture			4,284	4.44
16	Straw, 14¼ per cent. moisture			7,600 (probably)	7.87
17	Petroleum			20,240	20.33
18	Petroleum oils			27,531	28.50
19	Coal gas, mean of Ross and Harcourt			34,292	35.50

THE BESSEMER SPECTRUM AND STEEL BLISTER.

From "Iron."

AT the last meeting of the Société de l'Industrie Minérale, at Saint-Etienne, M. Pourcel reported that a new fact in relation to the spectrum of the Bessemer flame has been observed by M. Legat, at the Saint-Etienne Steelworks, and verified at Terrenoire by M. Deshayes. In treating siliceous pig the complete spectrum of the Bessemer flame may be produced at will by throwing a few pieces of carbonate of lime into the crucible during the period of combustion of the silicon, or first period, as it is termed, during which flame never appears and the spectrum is absent. This phenomenon, easily explained by the decomposition of the carbonic acid of the limestone, supports the opinion which attributes the groups of green and red rays of the Bessemer spectrum to the combustion of carbonic oxide under pressure at a high temperature, not to the combustion of iron and manganese.

M. Meurgey asks if the spectrum lasts long, and M. Pourcel states that its duration is proportionate to the quantity of

limestone used. Mr. Henry is unable to see why carbonic acid should be decomposed in this particular case and originate the spectrum. Mr. Snelus had analysed the gases given off at the Bessemer converter at different points of the operation, and found that a considerable quantity of carbonic acid was produced during the first period. Why should not this carbonic acid be decomposed in the usual course of working, and so give rise to the spectrum?

M. Pourcel replies that the gases which issue from the converter are produced by a preliminary reaction. It cannot be admitted that the carbonic acid in the gases produced during the first period are intimately mixed with the mass of melted metal, and then it cannot be decomposed. In treating siliceous pig, and during the first portion of the operation, the action of the silicon predominates. It is a more oxidisable body than carbon; consequently, the quantity of the latter, which burns simultaneously with the silicon by intermolecular combustion (not direct combustion), can only be infinitely small; the carbonic oxide which results is therefore engulfed in an excess of air, which peroxidises it instantaneously. Snelus' analyses prove the presence of free oxygen and of a quantity of carbonic acid which is but feeble compared with the whole volume of gas produced. In the particular case in question, on the contrary, the carbonic acid of the limestone thrown into the converter is intimately mixed with the melted metal; it is therefore admissible that the silicon decomposes it under the influence of a double affinity, that of silicon for oxygen, and silica for lime. The reaction appears vigorous, it almost instantly produces a very intense flame. Without doubt, the carbonic oxide liberated, coming in excess into the converter, as happens in the second period of the operation, no longer finds sufficient free oxygen to become totally transformed into carbonic acid; it therefore comes to the neck of the converter and burns at the expense of atmospheric oxygen.

If this explanation is not true, it looks at all events like truth. It admits that the silicon decomposes carbonic acid, which is plausible, since this gas is an oxidising agent, at a high temperature, which the iron itself decomposes. It is now known the reducing power of silicon goes farther, since the presence of this body prevents the formation of carbonic oxide. It is on this reaction that the Terrenoire process of making solid steel is based.

M. Devillaine, the chairman of the meeting, invites M. Pourcel to explain this a little.

Without losing sight of the object of the discussion, M. Pourcel can give some information on the subject of making steel without air-holes, the Terrenoire company being protected by very exhaustive patents. From the time that the different phases of the Bessemer operation were explained, the means of running steel without flaw was really discovered. It was known that silicon prevents the formation of carbonic oxide; the principle was thus established and all that was needful was to deduce the consequences and follow up their applications. It was analytic means which led, at Terrenoire, to the practical process of casting steel without flaw. The facts observed were as follows:—In the Martin furnace as we softened a gray siliceous pig by means of successive additions of iron and steel we found, by taking samples after each addition, that the metal run was honeycombed with air-holes. This being proved, if the solid sample taken immediately before the rotten sample be submitted to analysis, silicon is found in the metal which is free from honeycomb, while the honeycombed metal may contain intermingled slag, but no free silicon. Such is the analytic result, the effects of which can be reproduced synthetically. If we add silicon, in the form of silicide of iron, to a prepared steel bath, the air-holes will completely disappear. The steel, it is true, is generally red short; its shortness has been, and still is, attributed to the presence of silicon, not merely by steel-makers, but the greater number of our most eminent chemists. The explanation is admitted only provisionally by M. Pourcel, who now thinks it subject to discussion. His own opinion is, that the silicon does not deprive steel of any of its qualities, in the proportions in which it is usually found—that it neither makes it red short nor cold short.

Bessemer showed, some eight or ten years ago, that air-holes in cast steel are

due to carbonic oxide originated in the liquid steel by an intermolecular reaction between the carbon of the metal and the ferric oxide formed during casting. If the metal remains liquid long enough the gases escape, but, generally speaking, the melting point of steel is but little higher than that of its solidification. The carbonic oxide thus remains imprisoned, and gives rise to air-holes, or silvery-looking cells, arranged symmetrically and perpendicularly to the greater axis of the ingot.

Silicon prevents the formation of these blisters, by reason of its being more oxidizable than carbon—by intermolecular combustion, of course—the oxidizing body being peroxide of iron or carbonic acid, or both; but then, instead of being a gas, the product of oxidation is a solid body, which originates in the mass of the metal, and is found uniformly distributed between its molecules. It is silicate of iron, it is slag interposed between its molecules which makes the metal red short and lowers its good qualities as a cast metal. The way to remove the slag is to add to it a base, which gives it fluidity. M. Pourcel uses manganese for this purpose, and herein is the principal point of the operation. Manganese, in the Bessemer process, serves to remove from the cast metal the peroxide of iron which it holds in solution; it reduces it to its minimum of oxidation, by taking an equivalent of its oxygen, and the union of the oxide of manganese with the silicate of iron gives a very fluid slag, which is liquated.

Troost and Hautefeuille, in the papers they have read before the Academy of Sciences, have confirmed this explanation of the action of the manganese added at the end of the Bessemer process, an explanation given by M. Valton, more than eight years ago, in a paper in the *Bulletin de l'industrie minérale*. The theory has now become practice, and practice fruitful in good results.

One of these has been deduced by M. Pourcel, who, for the silicide of iron, substitutes a double silicide of iron and manganese as the addition to a bath of steel meant to give unblistered metal. The two reducing bodies, silicon and manganese, act simultaneously on the melted mass to reduce the peroxide of iron and hinder the formation of oxide of carbon, and the result of their oxidation is a silicate of protoxide of iron and protoxide of manganese, very fluid at the temperature at which steel solidifies, and easily liquated. As to the silicide in excess, its effects are not harmful, M. Pourcel thinks. He is not able, he states, to relate the experiments on which they are based without going away from the subject under discussion, but they will, he hopes, be shortly laid before the society.

The principal manufacture described by M. Pourcel is simple to enounce, but difficult to carry out; the difficulties, however, have been in great part overcome, and at the Terrenoire Steel-works there is reproduced in cast steel almost every shade of difference recognizable in wrought iron, from the hardest to the mildest. The perfect homogeneity of these cast steels, resulting from their chemical composition and the perfect equilibrium of their molecules, produced by reheating or a varied tempering, are capable, in the opinion of M. Pourcel, of giving results which have never been obtained with forged steels.

In returning to the question of the Bessemer spectrum, M. Pourcel believed he had sufficiently proved that the addition of limestone to a siliceous pig treated in the Bessemer converter, may give rise to carbonic oxide during the period in which it is not produced normally, and he believes that the theory which attributes the complex spectrum of the Bessemer flame to the combustion of carbonic oxide at a high temperature under pressure is as defensible, in the present state of our knowledge of the phenomena of the spectrum, as that which attributes this spectrum to the combustion of iron and manganese.

M. Henry draws attention to the fact that Snelus' analyses prove that the quantity of carbon contained in the gases issuing from the converter attains its maximum towards the end of the operation, that is to say, at the moment when the spectrum fades and the yellow sodium ray alone continues; it is therefore surprising to see the effect diminish when the cause which engenders it, according to M. Pourcel's opinion, increases in intensity.

To this objection of M. Henry's, M. Pourcel opposes another. When the

groups of red and green rays have disappeared from the spectrum, the intensity of the flame is decreasing, and the yellow sodium ray is alone continued; if we go on admitting air into the converter, the iron and the manganese are oxidised with such rapidity that a great quantity of the metal is cindered in a few seconds and the entire mass would be rapidly cindered if the refractory bottom of the converter, eaten out in two or three minutes by the oxide of iron, did not allow the metal and cinder to run into the pit. This is a particular case where, if the iron and manganese, the iron particularly, for the manganese would rapidly disappear, gave a spectrum in burning it would be easy to observe it; for the flame though feeble, on account of the small quantity of carbon left, still remains, and the yellow ray is visible to the end, that is to say, so long as blowing lasts. M. Pourcel concluded by saying that both opinions have their reasons, but neither had reasons which could be regarded as irrefutable, and the truth had probably yet to be discovered.

NOTES ON THE HYDRAULIC AND OTHER CEMENTS AT THE PHILADELPHIA EXHIBITION.

By Q. A. GILLMORE, Lieut.-Col. Engineers, Brevet-Major General, U. S. Army.

Written for Van Nostrand's Engineering Magazine.

PORTLAND CEMENT.

Portland cement may be produced by burning with a suitable heat, usually of an intensity and duration sufficient to induce incipient vitrification:

1. Certain argillaceous limestones, or
2. Certain calcareous clays, or
3. An artificial mixture of carbonate of lime and clay, or
4. An artificial mixture of caustic lime and clay.

The burnt product is reduced to powder by grinding.

These four methods of making this cement were all represented at the Exhibition, and will be briefly described.

First Method.—By this method the cement is produced by burning and grinding an argillaceous limestone containing from 77 to 80 per cent. of carbonate of lime, and 20 to 23 per cent. of clay. The stone should be a homogeneous and intimate mixture of the constituent ingredients, and the clay in it should contain at least 1½ to 2 parts of silica to one of alumina. There are generally present also carbonate of magnesia and oxide of iron in small quantities, and sometimes, and not injuriously, a small percentage of alkaline compounds, but not less than 94 per cent. of the essential ingredients—the carbonate of lime and clay—should be present, in order to yield a Portland cement of first quality. The presence of carbonate of magnesia becomes seriously objectionable when its amount exceeds 3 per cent. of the whole.

Only two localities are represented by this method of making Portland cement, viz : Teil in France, on the River Rhone, and Coplay in the United States, near Allentown, Pa. The Teil cement is the unslaked residium produced in manufacturing the siliceous hydraulic lime of Teil. It is burnt at a lower heat than any other Portland cement exhibited.

The Portland cement made at Coplay is produced from an argillaceous limestone, which has for several years been used in making the quick-setting cement of that locality. The stone contains in suitable proportions all the essential ingredients of unburnt Portland cement, but it is not an intimate and homogeneous mixture of those ingredients, and when broken into fragments and burnt at a high heat it yields a heterogeneous mixture containing Portland cement, common cement, caustic lime and hydraulic lime. In order to make Portland cement from it, it is first finely ground between mill stones, then tempered stiffly with water and formed into irregular shaped lumps or balls. These, after partial drying, are burnt in intermittent upright

kilns, in layers alternating with layers of anthracite coal. The cement is known in the market as Saylor's Portland Cement.

At Seilley, in France, a small town only a few hours ride by rail from Paris, Portland cement was made, six years ago, by M. Francois Coignet, by a mode essentially the same as that pursued at Teil, but none of it was in the Philadelphia Exhibition, and I do not know whether the establishment is in operation at the present time or not, neither do I know of any locality except Teil and Sielley, in France, and Coplay, in the United States, where an argillaceous limestone is found, from which this grade of cement can be made without the addition of other materials.

Second Method.—Argillaceous chalk, or, as it is sometimes called, calcareous clay, of the same composition as the natural stone above mentioned, is used for making Portland cement by the second method, and either the wet process or the dry process may be followed. The wet process is the most common, and throughout Europe the prevailing custom is to burn it in layers alternating with gas coke, or anthracite coal, in an upright intermittent kiln.

The only locality known to furnish the material for making cement by this method is near Boulogne-Sur-Mer, France, where the extensive establishment of Messrs. Lonquéty & Co., is engaged in this business. The material is found in the inferior cretaceous formation, and consists of an argillaceous chalk, containing from 76 to 82 per cent. of carbonate of lime, and 18 to 24 per cent. of clay. The deposit is soft enough to be excavated with a pick and shovel, and it is manipulated by the wet process.

The *Third Method* consists in producing Portland cement by burning an artificial mixture of carbonate of lime and clay, and is specially applicable to localities where chalk or tender marl abounds. The hard compact limestone may also be used, although it must be borne in mind that the large consumption of power involved in the reduction of the hard carbonates to powder, places them under a disadvantage which practically excludes their employment in regions which supply chalk. Suitable clay is of more rare occurrence than suitable limestone, for the reason that the former must contain silica and alumina, not only in certain proportions, but in a certain state of comminution.

All the English Portland cements are made by the wet process, with a mixture of chalk—either white or grey—and clay procured from the shores or dredged from the bottom of the Medway or the Thames. The exhibitors were Francis & Co., Hollick & Co., A. H. Lavers, The Wouldham Cement Co., and Eastwood & Co., all of London. Eastwood & Co., exhibited briquettes of cement formed for testing, but none of the cement in powder.

The Scanian Cement Co., whose works at Lomma, near Malmö, Sweden, use cretaceous chalk and clay, operate by the wet process, and burn in upright kilns, with coke made on the spot from English coal.

The Wampum Cement & Lime Co., (limited) of New Castle, Lawrence Co., Penn., exhibited a cement made by the dry process from fossil limestone and clay, both being ground together in suitable proportions, and the mixture tempered with water, formed into bricks, dried in ovens, and then burnt in intermittent kilns.

Wm. McKay, of Ottawa, Canada, had on exhibition some patented cement made with a mixture of shell marl, clay, and a small percentage of carbonate of soda. It was prepared experimentally and has never been manufactured for market.

In the *Fourth Method* of making this cement, the carbonate of lime is burnt and slaked before the clay is added, and the proportions are correspondingly varied by making the proper allowance for the loss of weight by the first burning. The celebrated Vicat cement is produced by this method in France, by the wet process. A sample of it, informally exhibited by an importer, did not sustain its reputation for superiority to the average Portland cements made from carbonate of lime and clay, than which it usually commands a higher price in all markets regulated by intelligent discrimination with respect to quality.

The cement exhibited by Messrs. Toepffer, Grawitz & Co., of Stettin, Ger-

many, made from an artificial mixture of lime and clay, justifies, by its excellence, this method of manufacture.

(It may be stated here that "The National Portland cement company of Kingston," has been organized for making this grade of cement at Kingston, Ulster Co., New York, on the bank of the Hudson River, the materials employed being fuller's earth, kaolin and lime. They are thoroughly ground and mixed together by the wet process, although much less water is employed in the manipulation, than in either the English works on the Thames, or in the works at Boulogne, France. Samples of this cement recently tested gave excellent results, as good indeed as those obtained with the best article on exhibition.)

Other Portland cements besides those above named, were in the exhibition, and were carefully examined and tested, but as no information was furnished with regard to kinds of materials used, and the methods followed in their manufacture, no special reference will be made to them here, except to give them their proper place in the accompanying table, which assigns to them their relative value.

It is hoped and believed that the manufacture of Portland cement in the United States, has taken such a start, that in a short time, possibly within a few months, very little if any of the foreign article will find a market here, except upon the Pacific Coast where it will be procured by direct importation.

THE NATURAL QUICK-SETTING CEMENTS.

The natural light, quick-setting cements, known also as Roman cements, are produced by burning at a comparatively low heat, not greatly exceeding in intensity and duration what would suffice to expel the carbolic acid, certain argillaceous or siliceous limestones, usually containing less than 77 per cent. of carbonate of lime, or argillo-magnesian limestones which contain less than 77 per cent. of both carbonates, and then grinding the product to a fine powder between millstones. They can be, and in Europe were formerly produced artificially by burning a mixture of lime, or of carbonate of lime and clay, before Portland cement became known by the discovery that with certain definite proportions of the ingredients, and by burning at a high heat, the quality of the product was vastly improved. The greater value of the Portland cement, producing as it does a mortar possessing about four times the strength at much less than twice the cost of the light, quick-setting artificial cements, gradually drove these from the market, and their manufacture soon ceased and has never been resumed.

It is not to be expected that the use of the natural light cements will be altogether superseded by that of Portland. For certain purposes they are as necessary, not to say as indispensible, at the present day, as they were when their introduction revolutionized the former methods of executing sub-marine constructions in masonry, by taking the place of the feebly hydraulic mixtures made from hydraulic lime, trass or natural or artificial puzzuolana. They possess sufficient strength for the purposes to which they are usually applied, viz., for massive concrete foundations and walls, for the concrete hearthing and backing of thick walls faced with ashlar or rubble, and for conferring hydraulic energy upon mortar for stone and brick masonry. At the same time it must be admitted that for similar purposes, good Portland cement, suitably diluted with common lime, in order to bring it down to the standard of the natural cements, is, in most localities, the least costly of the two.

For concrete work laid green under water, these quick cements are almost invariably to be preferred in the hands of ordinary workmen, for the obvious reasons that most of them not only hold the sand together, while in the plastic state, more tenaciously than Portland cement, but their prompt induration arrests the washing effects of the water, and tends to prevent the progressive separation of the sand and cement, before it has had time to proceed far enough to produce serious injury to the concrete.

Selenitic lime, or cement, patented by General Scott, of England, is prepared by mixing and grinding together unslaked eminently-hydraulic lime of the argillaceous type, and calcined gypsum, in the proportion of 93 to 95 per cent. of

the lime, and 5 to 7 per cent. of the gypsum. When such a mixture is tempered to a paste with water, the slaking of the lime is prevented by the presence of the gypsum paste, and when made into mortar with the proper quantity of sand, it sets rapidly and well, and can be used for concrete, or mason's work, with a very considerable gain of strength. In Great Britain, the limes that have been found to answer the best for this purpose are the Burham, the Blue Lias, and the Barrow Lias, and none of them require the addition of more than 7 per cent. of calcined gypsum, to arrest their slaking in the presence of water and render them selenitic. In preparing the selenitic mortar, the proportion of gypsum for a given quantity of the lime is first mixed to a creamy paste in a portion of the water necessary to be used for the batch. After this the rest of the water is stirred in, then the lime is stirred in, and lastly, the sand is added and thoroughly incorporated. The mortar is then ready for use. No more mortar should be gauged than can be used the same day.

No suitable limes for selenitic mortar have yet been discovered in the United States. Several specimens that were hard, dense and strong, of selenitic mortar, plastering, and concrete, were exhibited by the Patent Selenitic Cement Company, of London, but their age and composition were not known. Some selenitic mortar was made under the direction of the agent of the company, with Howe's Cave hydraulic lime, rendered selenitic by the addition of five per cent. of gypsum. Equal parts of lime and sand were employed to render the results readily comparable with those obtained with the Portland and Roman cements. The specimens were not put into water after being moulded, and were tested when seven days old. The results are recorded in the accompanying table. Although the selenitic process confers great additional strength upon the Howe's Cave lime, it still falls far short of the English selenitic mortars, in consequence, it is claimed, of the unfitness of the lime for this process.

All the cements exhibited at Philadelphia were carefully tested before awards were recommended, by mixing them dry in each case with an equal measure of clean sand, tempering the mixture with water to the consistency of stiff masons-mortar, and then moulding it into briquettes of suitable form for obtaining the tensile strength on a sectional area $1\frac{1}{2}$ inches square, equal to $2\frac{1}{4}$ square inches. The briquettes were left in the air one day to set, then immersed in water for six days, and tested when seven days old. After thus obtaining the tensile strength in each case, the ends of the broken specimens were ground down to $1\frac{1}{2}$ inch cubes, which were used the same day for obtaining the compressive strength by crushing. The results, averaged from a number of trials with each sample of cement, and divided by $2\frac{1}{4}$ in order to get the strength per square inch, are recorded in the following table. It may be stated in further explanation, that although the table shows, beyond question under the conditions named, the strength of the several mortars at the age of seven days, and hence the relative value for building purposes of the several specimens of cement exhibited, it may not correctly indicate the relative merits of the customary productions of the several manufactories represented. Some of them may have used especial care in preparing the article exhibited, while others may have sent average samples from stock on hand.

The quality of the well-known English Portland cement is fairly represented in the table, while that of Lonquéty & Co., of Boulogne, France, is not, for they have heretofore sold in the American market by the cargo, a better article than they sent to the exhibition. The Scanian cement from Sweden was badly used, having been exposed for three months in a loose pile on the floor, before specimens of it were furnished for testing. Its strength was doubtless considerably impaired thereby, and the results obtained with it were lower than those previously reported by a Swedish engineer.

The Parian cements are not hydraulic, and are used only for interior work. They were mixed with an equal measure of sand, and tested when seven days old, but the specimens were not kept in water. They were allowed to harden in the air, in one of the casemates of Fort Tompkins, Staten Island, New York.

CRUSHING AND TENSILE STRENGTH OF THE HYDRAULIC AND OTHER CEMENTS AT THE PHILADELPHIA EXHIBITION, TESTED IN THE MANNER EXPLAINED IN THE FOREGOING NOTES.

	Name of Exhibitor and Place of Manufacture.	Crushing Strength.		Tensile Strength.	
		Average Strength per Sq. Inch.	No. of Trials.	Average Strength per Sq. Inch.	No. of Trials.
	PORTLAND CEMENTS.	Pounds.		Pounds.	
1	Toepffer, Grawitz & Co., Stettin, Germany	1,439	12	216	3
2	Hollick & Co., London, England	1,330	10	216	3
3	Wouldham Cement Co., London, England	1,140	12	199	3
4	Saylor's Portland Cement, by Coplay Cement Company, Coplay, near Allentown, Pa., United States	1,078	8	184	2
5	Wampum Cement & Lime Co., Newcastle, Lawrence Co., Pa., United States	968	12	168	3
6	Pavin de Lafarge, Teil, canton of Viviers, department of Ardeche, France	931	12	158	3
7	A. H. Lavers, London, England	926	6	192	2
8	Francis & Co., London, England	907	14	163	3
9	Wm. McKay, Ottawa, Canada	882	10	141	3
10	Borst & Roggenkamp, Delfzyl, Netherlands	826	12	132	3
11	Lonquéty & Co., Boulogne-sur-mer, France	764	12	108	3
12	Riga Cement Co., by C. X. Schmidt, Riga, Russia	693	5	134	2
13	Scanian Cement Co., Lomma, near Malmö, Sweden	606	14	112	3
14	Brunö Hofmark, Port-Kund, Esthland, Russia	580	6	154	2
	ROMAN AND OTHER CEMENTS.				
15	Coplay Hydraulic Cement, by Coplay Cement Co., Coplay, near Allentown, Pa., United States	292	8	38	2
16	Charles Tremain, Manlius, N. Y., United States	276	12	47	3
17	Allen Cement Co., Siegfried's Bridge, Pa., United States	276	12	43	3
18	P. Gauvreau, Quebec, Canada	234	8	47	2
19	Riga Cement Co., by C. X. Schmidt, Riga, Russia	230	6	44	2
20	Anchor Cement, by Coplay Cement Co., Coplay, near Allentown, Pa., United States	208	12	41	3
21	Cumberland Hydraulic Cement Co., Cumberland, Md., United States	196	12	41	3
22	Societé Anonyme des chaux eminemment hydrauliques de l'Homme d'armes, pres Montélimar, France	184	7	29	2
23	Howe's Cave Associ'n, Howe's Cave, N.Y., U.S., No. 1	183	6	28	2
24	" " " " " No 2	170	10	43	2
25	" " " " " No. 3	170	8	31	2
26	Società Anonima per la fabbricazzione del cemente provincia di Reggio, Emilia, Italy.....1st quality	181	12	27	3
27	" " " " 2d quality	154	12	22	3
28	Thomas Gowdy, of Limehouse, Ontario, Canada	126	8	23	2
29	A. H. Lavers, London, England	122	6	24	2
	SCOTT'S SELENITIC CEMENT.				
30	Patent Selenitic Cement Co., London, England (made with Howe's Cave lime and plaster)	298	20	52	5
	PARIAN CEMENTS.				
31	Francis & Co., London, England, 1st quality	1,175	8	181	3
32	" " " 2d quality	696	12	169	3
33	A. H. Lavers, London, England	205	6	51	2

IMPROVED CAST IRON.—Mr. J. G. Willans, of St. Stephen's Crescent, Bayswater, has patented a method of manufacturing a cast iron, containing a little silicon or phosphorus by melting down pigs in contact with carbon in a cupola furnace. Malleable castings and steel he makes from the cast iron.

THE USE OF THE MAGNETIC NEEDLE IN SEARCHING FOR MAGNETIC IRON ORE.

By Prof. J. C. SMOCK, of the State Geological Survey of New Jersey.

Transactions of American Institute of Mining Engineers.

The magnetic and polaric properties of magnetite, or magnetic iron ore, are fundamental facts in magnetism. The disturbing effect of this mineral upon the magnetic needle in land surveying must have been very early observed. The difficulties arising from this source are still almost insurmountable in making accurate surveys in districts where this ore occurs to any extent, either as a rock constituent, or in well-defined ore masses. In the Highland range from the Hudson to the Delaware Rivers, the ordinary method of running lines with the compass, is sometimes impossible, and property boundaries are located by well-established landmarks, rather than by the course of the needle. Notwithstanding these well-known facts, the general application of this property of deflection in the needle, by the presence of magnetite, to searches for this mineral, is comparatively of recent date. There are, however, authenticated instances of this use of the magnetic needle more than a century ago. The mining of iron ore in the Highlands began in the early part of the eighteenth century, and the Sterling, Ringwood, Dickerson, Andover, and Oxford Furnace Mines were all worked before the American Revolution. And these, with other old mines of this district, must have been opened shortly after the location of the larger patents and tracts of land, and the settlement of the country. And some of these ore masses were, most probably, discovered through disturbances observed in the action of the needle in making land surveys. This may have suggested the employment of the compass in searches for ore. Such use of the needle was made by the celebrated London Company, that took up the Ringwood tract. This company surveyed the country with thoroughness and success. And nearly all of the older and larger mines in this Highland belt are commonly reported to have been discovered through the use of the compass, in searches for ore.

The more general use of the magnetic needle for this purpose does not go back more than thirty years. In 1854, when the Geological Survey of New Jersey, under the direction of Dr. William Kitchell, began, the ordinary surveyor's compass was used by a few persons who were sufficiently experienced, or skilled by observation, to properly interpret its indications. At that time the number of large mines was not much greater than at the beginning of the century. The introduction of the miner's or dip compass shortly afterward, made the use of the needle much more convenient and extended, and work with it was done with much greater rapidity and accuracy than formerly. Contemporary with its introduction, began the greater frequency of discoveries, and the opening of many new mines and ore localities, so that this might be taken as an era in iron mining in New Jersey. Dr. Kitchell estimated the amount of iron ore raised in that State, in 1855, at 100,000 tons. In 1864, this had been increased to 264,600 tons, and in 1868, to about 300,000 tons. But the increase in the number of mines, from 1868 to 1874, is most remarkable. In the first-named year there were 115 mines and mine-groups, whereas, in 1874, the number of mines and ore localities had increased to nearly 200 in number.

It may be safely stated that all of these were first made known by the use of the needle. Or, in other words, the average annual production of the State had been increased fully fifty per cent. by the addition of these new producing localities found by the compass. So much the iron men owe to this little guide, or *true* divining-rod. It should also be stated, that in many cases there are no surface indications of ore, other than those of the compass.

At the present time, nearly every mine superintendent, and many landowners, have their dip compasses, and, as opportunity offers, go out in search of new lines of attraction. A few persons follow this business as a specialty, and open

mines and deal in mineral properties. They are known as "ore hunters," or "prospectors," or "mineral dealers." For several years preceding the panic of 1873, the increasing demand for ore stimulated the search for new supplies, and many lines of attraction were found, and nearly every farm in this long belt was covered by a mineral lease.

Magnetism of Minerals and Rocks.—Magnetite is not, however, the only mineral which may disturb the needle and exhibit the deflection from the plane of the magnetic meridian termed *attraction*. Nor is this phenomenon of deflection confined to rocks containing this mineral. A large number of minerals are capable of producing slight deflection when they are brought near the needle. Serpentine, amphibole, pyroxene, hematite, and franklinite are some of the more powerful of these in their effects upon the magnetic needle. Many rocks also show some magnetism, particularly the darker-colored and more dense, igneous and volcanic rocks. This applies to the rock in masses as well as in hand specimens. In nearly all cases the magnetic disturbance is increased by heating to fusion or by oxidation. Probably in all these cases the magnetism is closely related to the presence or formation of both ferrous and ferric oxides in the mineral or rock species. Many of these exhibit polarity as well as magnetism. The greater intensity of this disturbing force in rocks and ores near the surface may be thus explained by an oxidation process through the agency of atmospheric forces. For a full statement of this subject of magnetism of minerals see an article by H. Tasche in *Jahrbuch der Kaiserlich-Koniglichen Geologischen Reichsanstalt*, VIII. Jahrgang, 1857. These phenomena observed in other minerals are interesting, but not of so great practical importance, since the experiment made with delicate instruments rarely showed more than two degrees of deflection, and practically they may be neglected. Very accurate and detailed magnetic surveys will yet be needed to embrace these elements in their range of work, and these elements will have to be eliminated to get at the correct indications coming from magnetite alone. Several lines of attraction observed in New Jersey, as yet unexplained, may be owing to the presence of strata containing these minerals, but it is very doubtful.

In practice, the attraction is to be referred to the near presence of magnetic iron ore, although the converse is not always correct, since there is a great range in the magnetic intensity exerted by ores, and some are so slightly magnetic that the deflection is perceptible only when the experiments are made with extreme care. Thus it is possible to pass with a dip compass right over large veins of ore, and yet fail to discover any attraction. Slight attractions over large and well-known veins are common in New Jersey. But careful surveys will generally reveal the disturbing effect and indicate ore. On the other hand, strongly magnetic and polaric ores are also common. In some instances the attraction is felt powerfully through wide intervals of rock or dirt or air. Hence no conclusions can be safely drawn from the amount of deflection or the magnetic intensity. These differences in the ore render the work of observation in some localities extremely easy, while in others there is need of repeated work, and that done slowly and cautiously.

As a rule the surface ores are most thoroughly magnetic, and this fact makes the survey of unexplored ground more easy. This difference between surface and bottom ores can be seen at almost any mine in this region.

Geological Occurrence of Magnetite in New Jersey.—The magnetite, as is well known, in this highland range, occurs either as a constituent of the rock strata, or in lenticular masses, imbedded between strata of rocks or walls. These ore bodies, in nearly every instance, have their shoots or longer axes in northeast and southwest lines, descending or pitching to the northeast, and they dip toward the southeast, and generally at steep angles. They may, therefore, be considered as approximately lying in the magnetic meridian and in a position to be influenced by terrestrial magnetism. Such an ore body would, therefore, have one pole at the uplifted or southwest end, while the other would be depressed beneath the surface toward the northeast. And the former ought to attract the north or positive pole of the magnetic needle, giving what is termed positive attraction, while the other end would

exhibit a negative attraction. Or we may look at the two sides of this flattened, cylindrical ore body, the northwest and southeast, as poles, in which cases the former would give a negative, the latter a positive attraction. And experiments everywhere show these to be the results, just as here predicted of them.

But these ore masses or veins do not all trend in the above stated general or prevalent direction. Sometimes their course is from east to west or approximately such, while in other instances the trend or strike is more nearly north and south.

In the east and west strike the two sides of the vein constitute the poles, and of course such lines are necessarily short, and the magnetism feeble. The more nearly the axis of the shoots of ore or vein corresponds to the magnetic axis, other things being equal, the stronger the magnetism and the more clearly the line and character of the attraction.

From these general statements it will be evident that positive attraction will be most commonly observed, the northeast end being too deeply buried to exert any measurable effect upon the compass at the surface, and as a rule the attraction diminishes toward the northeast until it is gradually lost. But from the geological structure of this region it is well known that these veins are very frequently broken by faults or consist of separate shoots, lying in a general northeast and southwest direction. In each of these cases there are a series of ore masses, and the opposite ends of these must show opposite kinds of attraction.

Hence, where there is a fault, and at the interval between two distinct shoots, both positive and negative attraction will be observed within short distances. On the south side it will be negative, on the north positive. Hence, a change from positive to negative entirely across the vein indicates a fault. Such transitions are common, and when met with the projector understands it to be a fault, or off-set. It is possible, therefore, *a priori*, to predicate the character of the attraction, if we have given the mode of occurrence of the ore. And from these the converse reasoning is safe, and practice, repeated in hundreds of cases in mining in New Jersey, has proved the correctness of these deductions.

Styles of Compass.—Formerly the ordinary pocket box-compass, in which the needle is horizontal, was used in searching for attraction, the observer holding it in his hand and noting from point to point the amount of deflection from the magnetic meridian. Sometimes, and where a more careful survey was required, the land surveyor's compass was used, and then lines were run back and forth, across the course of the vein, sighting ahead and noting from point to point in these lines the bearing of the object toward which the line was directed. When these lines were properly located, and the points of observation fixed, and the several observations on them recorded, good work was done. But it was necessarily slow, as each observation required some time, particularly if the attraction was slight.

About ten years ago the miner's, or dip-compass was introduced. This has its needle balanced on a horizontal axis, and free to move in a vertical plane only. In the most common form this is from two to four inches in length and is shut in a flat, circular brass box with glass sides, in some cases open, in more improved forms protected by movable brass plates or covers, which are taken off while in use. This style of compass has superseded the horizontal surveyor's instrument, and has come into very general use. It is often called the dipping-needle or dip-compass.

As in this form the needle cannot move horizontally, care must always be taken to ascertain the magnetic meridian, and to hold the instrument in the plane of that meridian, otherwise the needle, under the influence of terrestrial magnetism alone, will assume an inclined or vertical position, and thus show a dip, or attraction, where, in reality, there is none. Neglect of this precaution has misled many an observer, and intentional disregard of it has very frequently deceived the ignorant or unsuspecting. The extent to which deception in this manner has been practiced is hardly conceivable by those unacquainted with the magnetic iron ore districts of the Highlands.

In Sweden, a miner's compass, having its needle mounted upon a pivotal joint,

which allows of motion, both vertically and horizontally, and inclosed in a glass sphere, or cylindrical brass case, has been used in ore searches. But there is objection to this form in the unsteadiness of the needle, which has so much play that more time is requisite in making observations with it.

A newer form, designed by Prof. Cook, of the State Geological Survey of New Jersey, about five years ago, and constructed by W. & L. E. Gurley, of Troy, removes the objection in the Swedish compass, by allowing the needle, which is balanced on its horizontal axis, to move horizontally through a small fraction of a great circle. This, therefore, shows the magnetic meridian much more quickly than the Swedish instrument; and then, if there be any attraction, it is manifested in the dip, avoiding any possible danger of deception, through the action of the earth's magnetism upon a needle not placed in the magnetic meridian. This most improved compass has its movable brass sides for safety in carrying, and the ordinary ring set in the brass edge, whereby to hold it. The graduated circle is the same as in the old form. Those who have had much experience in magnetic surveys, give the preference to this compass, as the most accurate, convenient, and most efficient, either for rapid preliminary observations, or for detailed exploration.

In use, the compass is generally held about on a level with the eye of the observer, or so that he can conveniently watch the movement of the needle, and read off the graduated circles the amount of dip. After some experience great dexterity is acquired, and from the vibrations, the experienced eye can readily detect what will probably be the character and the amount of the dip, or attraction. Such an observer may move along on a slow walk and observe, or, as it is technically termed, *catch* the attraction, if there be any in the course he may follow.

Surveys.—In a preliminary survey of any given tract, the usual practice is to go rather rapidly on zigzag lines, from northwest to southeast; or, if attraction be known, or found at any given point, to walk northeastward and southwestward from that point, following on the supposed, or assumed course of the ore, and thus ascertaining its longitudinal extent. This gives the general direction and length of the line, or belt of attraction. This preliminary survey does not generally require more than a single line of observations, and these are not located or recorded, excepting so far as the observer may refer them, in his memory, to any landmarks that may be prominent or convenient for further observations.

Detailed surveys, or what may be properly termed "magnetic surveys," may be more or less varied, according as the nature of the attraction may seem to require a greater or less number of observations within a given area.

In general, the most convenient and most expeditious method, and, at the same time, that which is best suited to show the character of the attraction or observations, consists in taking observations on lines at right angles to the course of the vein, or across the belt or line of attraction. Where the prevailing course, or strike, is northeast and southwest, as in the Highlands, these should be northwest and southeast lines. Of course, they may be at greater or less distances apart, according as the nature of the attraction may indicate, or the degree of detail demanded in the survey. In general, they may be from 50 to 200 feet apart, or in exceptional cases as close as 20 feet. The stations, or points of observation in these lines, may likewise be at varying distances, from five to twenty-five feet apart. Ten feet has been found to be convenient, and sufficiently close for careful and valuable surveys. Such detailed observations, to be of value, must be located and recorded; or, in other words, mapped. For this purpose it is easier to run parallel lines, or such as are approximately so, and make the observations at regular intervals.

Stakes may be driven at the ends of these, and a subsequent survey may be made to locate them. The observed dips, or the amount of attraction, can then be placed at fixed intervals on these lines. Such a method is much more expeditious than a far more detailed survey at *irregular* points. While a great deal of work has been done by the numerous prospectors in this iron ore district, and large areas have been covered by a network of closely placed observa-

tions, very little work has been recorded on maps.

Geological Survey of New Jersey.—The geological survey of New Jersey has traced out some lines of attraction, and placed them upon record—upon geological maps—but these do not show the character or the amount of attraction. The scale of these maps is too small for the exhibition of these facts. Three sketch-maps, but of limited areas, giving the observations and their location, appeared in the "Annual Report for the year 1873." These were on a scale of eighty feet to an inch. In these the dots represent the stations, and the figures the observed amount of attraction, the minus sign indicating a negative attraction, and the figures alone positive attraction.

During the past summer the Green Pond Iron Mining Company had a magnetic survey made of its large tract of 600 acres of mineral land, in Morris County, about fifteen miles south of Dover, N. J. This was crossed in a preliminary survey by lines 200 feet apart, running northwest and southeast, and then the areas, where over 5° of attraction were observed, were covered by lines fifty feet apart, with observations at intervals of fifteen feet. This map shows three separate lines or belts of attraction which trend north 54° east (referred to true meridian). The openings on one of these lines have been such as to expose a large *vein* of ore, or rather a long line of *shoots* of ore.

Deductions from Indications.—Having made such a survey, we are very naturally asked what inferences follow certain indications or what are such surveys worth? The diversity in the character of lines of attraction may be very great, almost as varied as the possible arrangement of the stations, but certain general characters are recognized as indicative of corresponding occurrences of ore beneath, and all the varied phenomena may be classified in a few groups, described by a few generalizations.

The line of attraction may be long and steady or regular, that is, there may be a line of maxima dips, from which, toward either side, these diminish and at length disappear; and these maxima may correspond more or less closely in amount as well as in location. Such a line indicates regularity below, either in the form of an ore vein or a series of stratified ore-bearing rocks, of nearly homogeneous character throughout. Conversely, if in the line the attraction be irregular in amount, very strong in close juxtaposition with slight or weak attraction, or if the maxima in the several parallel lines which cross the vein, are not in line, but varying from side to side or in amount, on one slight, on the next strong, etc., such indications show irregularity in the occurrence of the ore.

Generally such very irregular attraction is found wherever magnetite occurs as an inconstant and accessory mineral constituent of unstratified, granitic, or syenitic rock masses. Inasmuch as the attraction in such places is apt to be very strong, frequently holding the needle vertically, it is likely to mislead the ore hunter, and many instances of fruitless work in digging and shafting for ore on such attractions have been observed in New Jersey. Popularly a few strong observations far outweigh the longer lines of constant but slight dips. But there is a variation in the character as well as in the amount of the dip, that is, the dip or attraction is sometimes positive and sometimes negative. And here, too, the transitions from the one to the other may be very sudden, and frequently recurring with limited areas.

From what was stated at the outset, positive attractions would be anticipated as the predominant character, prevailing along the whole line, excepting on the northwest side, and in those cases where the ore may not be continuous, either on account of faulting or in consequence of its occurrence in separate shoots, lying *en échelon* in the general course of the vein. In these a negative attraction would be anticipated, and this is found to be the case. And hence such transitions from positive to negative are indications of breaks in the ore mass, faults or separate ore-shoots. Repeated observations over faults prove this.

Conclusions.—This method of examining ground for magnetic iron ore is so well understood and so extensively practiced in New Jersey, that such a description is hardly more than a statement of facts there gathered.

In the further extension of such surveys, greater care is requisite both in the

manner of taking observations and in recording them upon carefully constructed maps. Hereafter more attention must be paid to the slighter attractions and to the regular work of accurately mapping them. Such care is necessary, not only to discover new lines, but also to so ascertain the character of known ones as to enable the miner to locate properly his trial pits and shafts. And it appears proper to put this before the attention of mining engineers and geologists, wherever there are magnetite iron ores, since careful preliminary works with the magnetic needle may in other States as well as in New Jersey, largely increase the number of localities whence our supplies of ore may be drawn.

ON THE WORKING OF STEEP GRADIENTS AND SHARP CURVES ON RAILWAYS.

By Capt. HENRY WHATLEY TYLER, Assoc. Inst. C. E.

Proceedings of the Institution of Civil Engineers.

The comparative terms, steep and sharp, have acquired at the present day a signification very different from what they conveyed to Engineers a few years since. The locomotive engine has been gradually trained and adapted to gradients of 1 in 100, 1 in 50, 1 in 25, and 1 in 12, combined with curves of from 30 chains down to 15, 10, 5, and even 2 chains radius; and during all this progress, the result of so much labor and ingenuity, the system of bite, or adhesion, by plain surfaces, has steadily triumphed as a means of converting steam-power into tractive force. The well-known rack-rail of Blenkinsop, as well as the Archimedian screw of Grassi, and the grooved wheels of other inventors, have all succumbed before it. The coefficient of adhesion was always in the first instance under-estimated. Legs or feet were most cleverly contrived to enable engines to walk, so to speak, before they could run; and the central rail system of Vignoles and Ericsson, patented so far back as 1830, was intended to provide extra adhesion on what are now considered moderate gradients, in place, apparently, of the rack-rail. The defects of the rack-rail appear to have been,—the risk of fracturing the teeth; the liability of the teeth to be choked with dirt, snow, or ice; the slip which resulted as the teeth began to wear, and the continued blows which they occasioned to the locomotive, causing it to be, in fact, always "on the rack." Grooved wheels afford obviously increased bite; but there must be, when they are used for locomotive purposes, continual abrasion from unequal travel of the surfaces in contact, with increased friction on curves, and some loss of power, in proportion to the increased bite obtained, from what may be termed back-adhesion. The screw of Signor Grassi—to work under his engine on a series of rollers along the permanent way—was reported upon by Captain Moorsom, in 1857. Captain Moorsom expected a load of 80 tons to be taken by its means, in place of 50 tons by "an ordinary bank-engine," up 1 in 20; but he stated that there would be three peculiar difficulties to contend with:—(1) The maintenance of exact action between the wheel and the screw. (2) The friction of the rollers. (3) Economy of maintenance of engine and road. The screw was to be 13 inches in diameter, winding round a shaft 7 inches in diameter, with a pitch of 12½ inches, and 5 feet 4 inches long, grasping two rollers at a time on the permanent way. These rollers, 8½ inches in diameter, were to be placed 3 feet 2 inches apart from center to center. A bevelled wheel on the driving-axle of the engine was to be connected with a crown wheel on the end of the screw shaft, and the proportions were to be such, that each revolution of the driving-wheel was to turn the screw twelve times. This system was ingenious, but wanted many of the advantages which will be hereafter referred to as arising out of the use of the central rail.

In this country the Lickey incline of 1

in 37, the incline of 1 in 30 on the Folkestone Harbor branch, the Oldham incline of 1 in 27, and the navigation incline of the Taff Vale Railway of 1 in 18, have, with others, been worked for a greater or less number of years with what may be called engines of ordinary construction. And it was stated in this Institution, in 1858, that an eight-wheel coupled engine, weighing 24 tons, was in the habit of taking its tender and a carload of iron, together weighing 25 tons, over a gradient steeper than 1 in 10, at a speed of from 8 to 10 miles an hour. This required, however, as will be observed, an adhesion of between one-fourth and one-fifth of the weight of the engine, which is more than could be relied upon, at all events in this climate. But in conveying heavy loads up gradients much less steep than those referred to, a want of extra adhesion has been seriously felt, and various expedients have been resorted to for obtaining it. The most comprehensive proposal with this view was that of M. Flachat, who, in a paper laid before the Society of Engineers in Paris, in 1859, desired, in constructing railways over the Alps, to utilize the adhesion, not only of all the wheels of the engine and tender, but also, by the use of additional cylinders, &c., to them, of all the vehicles composing a train. M. Flachat says, "La puissance motrice, au lieu d'être concentrée sur six roues, s'appliquerait ici à 32 ou 40 roues; elle sera donc dans des conditions d'utilisation bien supérieures. Ce qui manquera aux unes, par une diminution éventuelle d'adhérence, sera reporté sur les autres, de telle sorte que cette puissance ne pourra s'annuler à la fois entièrement pour tout un train, comme cela a lieu par le patinage de la machine." Mr. Sturrock has acted in this country, *sed longo intervallo*, in the same direction, having contented himsef with adding cylinders and the necessary apparatus to his tenders, which he has now for some time employed as assistant engines on certain parts of the Great Northern Railway. The engine and steam-tender together weigh, when fully loaded, between 60 and 70 tons.

M. Thouvenot, on the Continent, and Mr. Fairlie—who has published a most interesting pamphlet on the subject—in this country, employ two tank-engines in one, placed, as it were, back to back, and united as to their boilers and fireboxes. They thus obtain double engines, which are intended to be worked by two men only, which have double power, intended to run either end foremost, and which are adapted for sharp curves. There being four cylinders, the wheels under each engine are coupled together, independently of those under the other engine. M. Thouvenot's engine weighs upwards of 80 tons, while Mr. Fairlie estimates his heavy goods engine at 60 tons, and states that it would draw (including its own weight) 170 tons, up a gradient of 1 in 12, at 10 miles an hour. But this is allowing between one-third and one-fourth for adhesion; whereas if one-ninth were allowed for adhesion, the same engine would only be able to take 72 tons altogether, or 12 tons besides its own weight, up the same gradient.

In the ordinary system of obtaining adhesion by bearing-wheels only, whether of an engine and tender, or of a double engine, or of two engines coupled together, the weight of the motive power requires to be increased for a given amount of adhesion, in proportion to the load or to the steepness of the gradient. The limit of the gradient up which such an engine can take a load may roughly be defined by the coefficient allowed for adhesion; and it is necessary, of course, in practice, particularly on very steep gradients, to allow for, not an average, but nearly the lowest, rather than the best adhesion that can be obtained. If, for instance, one-tenth be allowed, then 1 in 10 is (omitting friction) the gradient on which an engine may move itself, but on which no load can be taken. If one-twelfth be allowed, then 1 in 12 is the gradient of no load; and so, in all climates where from one-tenth to one-twelfth only of adhesion can be relied on, no amount of increase in weight, or arrangement of the parts of an engine, will admit of trains being worked on such gradients. Mr. Fell, therefore, when brought face to face with the Mont Cenis, on which the adhesion may vary from one-sixth to one-twelfth, and on which gradients were required of 1 in 12, was obliged to adopt some other method than that of trusting to adhesion by bearing-wheels; and having a high summit to surmount, it was of great im-

portance to him, with reference to cost of working, to save weight in the engine as well as in the train. By wisely adopting the principle of horizontal wheels and a central rail, he found the means of doubling the adhesion, at the same time that by the use of steel, he made the engine lighter than it would otherwise have been.

The central rail system was first patented, as already stated, for extra adhesion, by Mr. Vignoles, and Mr. Ericsson, on the 7th September, 1830; and next on the 15th October, 1840, by Mr. H. Pinkus, in England. It was proposed by the Baron Séguier, in December 1843, to "L'Académie des Sciences," as a means of safety for general application, and patented by him three years later. It was again patented in England by Mr. Seller, under the name of A. V. Newton, on the 13th July, 1847; and lastly by Mr. Fell, who has, with the assistance and influence of Mr. Brassey, been the first to carry it into practice, in January and December, 1863.

It has been tried with two engines, and upon two experimental lines. The first experimental line, 800 yards long, containing 180 yards of straight line, on a gradient of 1 in 13.5, and 150 yards of curves, with radii of 2½ and 3½ chains, was on the Cromford and High Peak Railway, in Derbyshire. The second, a mile and a quarter long, on an average gradient of 1 in 13, containing, besides others, 480 yards of curves with radii varying from 4 to 2 chains, and terminating at an elevation of 5,815 English feet above the sea, was laid on the road over the Mont Cenis.

These lines were laid on a guage of 1.10 mèter or (3 feet 7⅜ inches) with bearing rails of the ordinary description, but with a third rail laid on its side horizontally and centrally between them at an elevation (to its center) of 7½ inches above them. On the Mont Cenis, the central and bearing rails were borrowed from the Victor Emmanuel Railway Company, and weighed about 75 lbs. to the lineal yard. The chairs which supported the middle rail were partly of wrought and partly of cast iron; they weighed 20 lbs. each at the joints, and 16 lbs. each in the intermediate spaces: they were placed six feet apart on the straight line, and from 2 to 3 feet apart on the curves; and they rested on longitudinal timbers, 8 inches deep by 12 inches wide, which were spiked to the transverse sleepers.

The first engine weighed 16 tons when loaded with coke and water. It has a heating surface of 420 square feet, and a grate area of 6 feet 6 inches. It is provided with four cylinders, two outside cylinders 11¾ inches in diameter, with a stroke of 18 inches, for working four coupled vertical wheels 2 feet 3 inches in diameter, with a wheel-base of 5 feet 3 inches; and two inside cylinders 11 inches in diameter, with a stroke of 10 inches, for working four horizontal coupled wheels 1 foot 4 inches in diameter, with a wheel-base of 1 foot 7 inches. It has a pressure of 16 tons on the horizontal wheels, or about the same weight as is carried by the vertical wheels. Guide-wheels have also been added to the trailing end, to act upon the middle rail.

The machinery of this engine is too much crowded together for convenience in re-adjustment or repair; its boiler power is not sufficient for working the traffic of the Mont Cenis; and the oil from its machinery falls upon the horizontal wheels, and deprives them, to some extent, of their power of adhesion; but it has answered its purpose in proving the principle which it was constructed to test, and has been, considering its novelty, a surprising success.

The second engine, constructed specially for the Mont Cenis, is partly of steel. Its net weight is now 14 tons, and its mean weight, when fully loaded with fuel and water, 17 tons, of which 2 tons 13 cwt. is for the machinery connected with the horizontal wheels. The boiler is 8 feet 4½ inches long, and 3 feet 2 inches in diameter, and contains one hundred and fifty-eight tubes of 1½ inch external diameter. The fire-box and tubes contain altogether 600 superficial feet of heating surface, and there are 10 feet of fire-grate area. There are only two cylinders, with a diameter of 15 inches and stroke of 16 inches, which work both the four coupled horizontal, and the four coupled vertical wheels, which are all 27 inches in diameter. The wheel base of the vertical wheels is 6 feet 10 inches, and that of the horizontal wheels is 2 feet 4 inches. The maximum

pressure in the boiler is 120 lbs. This engine, without guide-wheels before or behind, travels with its longer (horizontal) wheel-base more steadily than No. 1; its machinery is more easily attended to, and the pressure upon its horizontal wheels can be regulated by the engine-driver at pleasure from the foot-plate. This pressure is applied through an iron shaft connected by means of right and left handed screws with a beam on each side of the middle rail, and these beams act upon volute springs which press the horizontal wheels against that rail. The pressure employed during the experiments was from 2½ to 3 tons on each horizontal wheel, or 10 tons altogether; but the pressure actually provided for, and which may, when necessary, be employed, is 6 tons upon each, or 24 tons upon the four horizontal wheels. The vertical wheels are worked indirectly by piston-rods from the front, and the horizontal wheels directly by piston-rods from the back of the cylinders.

The Author himself observed, that No. 2 Engine was just able to move up a gradient of 1 in 12½ with 40 lbs. of steam-pressure. This engine developed 12 horse-power per ton of its own weight; but it is believed that by some alterations in the boiler, as well as in other parts of the engine, in which steel may be substituted for cast iron, something like 15 horse-power per ton may ultimately be obtained, as against 20 horse-power per ton which is afforded by steam fire-engines.

It was remarked during the later trials, that the engine and train gained speed on the sharpest curves. This effect, so contrary to general practice, was produced, partly by the action of the horizontal guide-wheels, which kept the engine and the wagons in their proper positions with respect to the rails, and partly to the fact that the gradients on the curves had been slightly eased, while the gradients on the straighter portions had been made proportionally steeper, with the intention of as nearly as possible balancing the resistances. There is the less practical difficulty in carrying out this advantageous arrangement upon very sharp curves, because such cannot of course be of great length.

The advantages of this system for mountain passes are very great. The middle rail, besides being of service in the ascent, affords the means of applying pressure-breaks, acting with any amount of force, to any number of vehicles in the descent, and thus renders the descent safe, and supplies a remedy against bad consequences from a fracture of the couplings. It also prevents the engine, or any vehicles of the train that are supplied with guide-wheels, from leaving the line, from a defect in the permanent way or rolling stock. The force of the wind is at times so great on the Mont Cenis that it would hardly be safe, if only on that account, to take trains over it without the protection thus afforded.

There is another system for working steep inclines which has found support in Italy, and which it will be proper to describe here—that of Signor Agudio. In this system two stationary engines are employed, one at the summit and the other at the bottom of an incline plane. They have the same power, and they act upon the same double endless rope, which is kept stretched by a tension wagon hanging upon it at each extremity. This rope runs between the rails, and over two systems of wheels worked by the stationary engines, from which it receives its movement by friction. It does not act directly upon the train, but is connected with an engine which may be called the locomotive of the system, and has received from the inventor the name of "Locomoteur funiculaire." This is a vehicle 22 feet long, supported on a bogie-frame at each end, and carrying a system of drums and wheels, by the action of which the required motive power is obtained indirectly from the moving rope. The two portions of rope act upon separate wheels, the wheels set the drums in motion, and the drums climb a heavy stationary iron cable, firmly fixed at the summit and weighted below, which is called the "cable of adhesion." The ascending portion of the moving rope has two turns round two wheels on the left side, and the descending portion two turns round two wheels on the right side of the locomotive, the front wheels in each case remaining free, and being used for conducting the rope only, while the hind wheels transmit to the drum the moving power of the rope. The ascending rope acts through its (left) hind wheel upon a middle friction drum,

which is compressed between the outer main drums by the force of the rope passing over them, and which thus turns the main drums on each side of it by adhesion. The descending rope acts through its (right) hind wheel upon a pinion and a rack in the inner circumference of the hinder drum. The drums being set in motion, the locomotive is moved by their friction upon the cable of adhesion which has two turns round them.

The middle drum which transmits the force of the ascending portion of the rope to the main drums, and the rack and pinion which transmit the force of the descending portion to the hinder drum, are so proportioned that the rope moves at two and a quarter times the speed of the locomotive; and as the two portions of the rope work equally, the strain on the rope is, excluding friction in both cases, $\frac{1}{2.25}\times\frac{1}{2}=\frac{1}{4.5}$, or 2-ninths of what it would be in the case of a single rope acting by direct tension in the ordinary way. The moving rope of the system may therefore be proportionately diminished in strength and weight, or a greater length of inclined plane may be worked than under the ordinary system, with greater safety, though at the expense of a certain amount of complication.

The hinder rope-wheels of the locomotive are provided with gearing which will admit of their running free, or with their shafts, at pleasure. Before starting they are allowed to run free, and when a certain velocity has been attained, that which is connected with the friction drum is suddenly put into gear, and the excess of velocity is utilized in overcoming the inertia of the train and the apparatus. In ascending, the train may at any moment be stopped by putting these wheels out of gear and applying the break. There is a break attached to one of the drums and a sledge break on the rails, which may be used in the descent, when the moving ropes are stationary and the rope-wheels run freely on their shafts.

Some experiments which were tried with this system on the Dusino incline between Turin and Genoa appear to have given great satisfaction to the Commissioners of the Royal Institute of Lombardy. The incline was 2,400 mèters (1½ mile) long, on variable gradients of 1 in 26 to 1 in 31, and the sharpest curve had a radius of 350 mèters, or 17½ chains. The total passive resistance for a train of 120 tons on this incline was estimated at 44 per cent.; and it was calculated by the inventor that he would be able to save 605,245 francs out of 776,228 francs annually in the working of the Giovi incline. He proposed, however, to employ water-power for his stationary engines.

The useful effect of the system is calculated at 57.7 per cent. by the inventor as the result of the experiments on a length of 1½ mile; at 50 per cent. for a length of 5 kilomèters (3 miles) by the Italian Commissioners who reported on the Mont Cenis Railway; and at 47 per cent. by M. Desbrière for a length of 6 kilomèters (3¾ miles). M. Desbrière represents it perhaps rather too favorably in allowing no diminution of useful effect as the gradients become steeper. It is true that the friction of the parts would remain nearly the same, but the weight of the locomotive being constant, it would bear a greater proportion to the trains as the gradients became steeper, and to that extent diminish the useful effect.

It is a question, whether, in the practical application of the system, the toothed wheels through which the force of the descending portions of the rope is applied, should not be replaced by wheels acting by adhesion; and it is a still more important question whether, supposing the principle of the moving ropes to be applied, a middle rail ought not to be employed in the place of the "cable of adhesion," as has been, indeed, already proposed by the inventor. Horizontal pressure-wheels in the locomotive might be made to act with any required amount of pressure upon a middle rail, in place of the drums acting upon the cable of adhesion, and many important advantages would thus be obtained. 1. The weight of the locomotive might be reduced. 2. Much sharper curves might be employed. 3. A greater degree of safety would be attainable in the important items of (*a*) preventing, by the use of the horizontal wheels, all risk to the locomotive or any of the vehicles behind

it from their leaving the rails, (*b*) affording a means of applying a break, by pressure upon the middle rail, which would admit of a train being stopped without difficulty upon any gradient.

A modified Agudio system—with the double-wire rope and a middle rail—worked by stationary engines, might probably in some cases be adopted with advantage for passenger traffic on gradients steeper than 1 in 10 or 1 in 12. The defects of the system—that it can only be worked for lengths of 4 to 5 miles, and that it does not admit of the use of very sharp curves—would be insignificant if gradients of 1 in 4 or 1 in 5 were employed in suitable localities. At high elevations, however, where the ropes would be liable to be covered with snow and ice, the system would be inapplicable, at all events excepting under complete cover; and steam-power would be required, inasmuch as water-power would not be available in seasons of low temperature.

It does not appear that this system, or any other yet developed, can compete with the central rail system for general traffic on very steep gradients up to 1 in 10 or 1 in 12; and the principal questions that remain to be considered are, the relative economy of summit lines with steeper gradients, and tunnel lines with less steep gradients, and the limit from which the central rail may be profitably employed. The best comparison that can at present be made in regard to the former point is between the Mont Cenis Railway and the Grand Alpine Tunnel.

The Italian Commissioners who reported on the experiments on the Mont Cenis, themselves admit a saving of 84,000,000fr. out of 123,000,000fr. in favor of an improved and permanent summit line, as compared with the tunnel line which the Italian Government constructed to connect Modane with Susa. They arrive at this result by deducting 16,600,000fr. as the cost of an improved summit line, and 22,400,000fr. at which they estimate the capitalized difference of working expenses (over a super-elevation of 2,500 feet) from the estimated amount, as above, of 123,000,000fr. for the tunnel line. But Mr. Fell points out that they have omitted 10,000,000fr. for the portion of their own line between Modane and St. Michel: they have inadvertently charged 1,000,000fr. for extra rolling stock for the summit line twice over; and they have overcharged the capitalized extra working expenses by 10,000,000fr. on the one hand, at the same time that they have omitted 800,000fr.—the cost of the extra portion of the tunnel line from Susa to Bussolino—on the other hand. The Italian estimate thus modified shows a saving in favor of the summit line of 104,800,000fr. out of 133,800,000fr., or, in other words, places the total cost of constructing and permanently working this particular summit line at less than one-fourth of the tunnel line.

The Italian Commissioners who reported to their Government upon the best mode of crossing the Swiss Alps, took considerable pains, also, to calculate the relative cost of conveying passengers and goods by tunnel lines or summit lines such as that over the Mont Cenis. Taking into account the total capital to be expended, and the cost of working in each case, they came to the conclusion that the cost of the tunnel line would be: for goods, 28 centimes per ton per kilométer, and for passengers, 17 centimes each per kilomèter; as against on the summit line: for goods 10 centimes per ton per kilomèter, and for passengers, 6 centimes each per kilometer, showing that there would be a reduction of total cost amounting to about 64 per cent. in favor of the summit line, with a loss of time, for passengers, of thirty-eight minutes upon 48 miles against the summit line, in the passage of the Mont Cenis.

The particular gradients on which the central rail may properly be applied must, of course, vary with the coefficient of adhesion and other local circumstances, and be left in each case to the discretion of the Engineer.

Neglecting the questions of speed and steam-power, and assuming one-tenth as the coefficient of adhesion, then the proportions of net load that could be taken up the following gradients by two engines, each of 20 tons, one of ordinary construction, and the other with horizontal wheels and a supplementary adhesion of 1½, would be respectively:

For 1 in 20	20 tons net load for ordinary engine	or 1 to 4
	80 " " central rail engine	
For 1 in 16	12 " " ordinary engine	or 1 to 5
	60 " " central rail engine	
For 1 in 12	4 " " ordinary engine	or 1 to 10
	40 " " central rail engine	

Similarly for an adhesion of ¼:

For 1 in 20	39 tons net load for ordinary engine	or 1 to 3¼
	129 " " central rail engine	
For 1 in 16	27 " " ordinary engine	or 1 to 3½
	99 " " central rail engine	
For 1 in 12	15 " " ordinary engine	or 1 to 4½
	69 " " central rail engine	

But these advantages would, of course, only be available as long as the adhesion was insufficient in an ordinary engine for the steam power, and would disappear in such a case as that which—though it can hardly be credited—was reported from the Alleghany Mountains in America, in the Paper already referred to, where, on a gradient steeper than 1 in 10, an ordinary engine (with an adhesion apparently of ¼) is stated to have worked with a load. The following Table, from the Paper of M. Desbrière, before alluded to, gives the result of his calculations.

Table of minimum weight to be allowed, with an adhesion of one tenth to

(1.) An ordinary locomotive engine with wheels all coupled.

(2.) A central-rail engine, with 1.5 of supplementary adhesion, to draw a net load of 100 tons on different gradients, compared with the weight which would result, for each system, with heating surface corresponding to various speeds:

Gradients.	Weight necessary for adhesion of Locomotive Engines.		Speed in Kilometer per Hour.	Total Force.		Weight required for Steam Power.	
	Ordinary.	Central Rail.		Ordinary Engine.	Central Rail Engine.	Ordinary Engine, System Pétiet, 120 kilos. per H.P.	Central Rail Engine, 112 kilos. H.P.
Millims.	kilos.	kilos.	kiloms.	H.P.	H.P.	kilos.	kilos.
0	5.000	2.000	72	146.66	146.66	16.352	16.352
10	16.440	6.250	30	203.33	190.00	24.400	21.280
20	31.250	10.860	20	254.80	217.77	30.576	24.390
30	50.000	15.900	15	305.50	243.33	36.660	27.252
40	75.000	21.430	12	366.60	257.30	43.992	28.617
50	110.000	27.500	10	448.10	280.00	53.772	31.360
60	162.500	34.730	10	659.40	346.86	78.128	38.852
70	250.000	41.660	10	1,014.75	422.50	121.680	47.320
80	425.000	50.000	10	1,725.00	482.80	207.000	54.073
90	950.000	59.440	..	..	..	..	..
100	..	70.000	..	..	..	..	..

Precise calculation is, however, of limited value, when the coefficient of adhesion, the principle element, is so very variable. But no English Engineer would probably contemplate working any considerable length of railway permanently on a steeper gradient than about 1 in 25 without the margin for adhesion afforded by, and the additional safety of, the central rail; and it might, no doubt, be frequently used with advantage on gradients less steep than 1 in 25. A country which requires very steep gradients demands also, in most cases, very sharp curves; and the central rail contributes to safety as much in respect to the latter as to the former. It also contributes in an important degree to economy, by diminution of friction in passing round very sharp curves, by

which loss of power and wear and tear are equally avoided. And it may be added, in conclusion, as a result of experience, that the bearing-wheels of the engine left the bearing-rails once during construction, and once before the Italian Commission, on the Mont Cenis Experimental Railway, and were brought back to them on both occasions by the guiding power of the central rail.

SOME SPECIAL FEATURES IN LARGE AND SMALL GRAIN POWDERS.

By Major J. P. MORGAN, R.A.

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It is the third time that I have read a paper on the subject of gunpowder. The first was on the determination of its explosive force, without an accurate knowledge of which no scientific progress can be made in its manufacture. The second showed the difficulties which had been encountered, and the success which had been achieved in the manufacture of pebble powder. In the present paper, assuming the conditions on which the thorough ignition of a charge mainly depends, I intend to show how great an approximation there is to these conditions in the special features which regulate the burning of the individual grains of powder themselves, and how this depends not only on the size of the grains, but also on the facility with which the flame can penetrate towards the centre of the grain, and on the rate of burning of the particles of charcoal of which it is partly composed.

It is not many years since two sorts of powder only were sufficient for nearly every requirement of the Service, viz., Large Grain or L.G., for guns, and Fine Grain or F.G., for small arms. Both of these powders were manufactured in the same manner from the same description of charcoal, viz., alder or willow, differing from each other only in the sizes of the grain, L.G. being sifted between meshes of 8 and 16 to the inch, and F.G. between those of 16 and 36.

On the introduction of rifled small arms, F.G. was found unsuitable, and the first and most important alteration was the substitution of dogwood for alder, or willow charcoal. This necessitated the entire separation of the manufacture of small arm powder from that of powder for guns. The first powder of this description was made in 1859, and was of a size 16 to 24-mesh. It was known as Enfield Rifle, or E.R. powder. In 1860, the size of grain was increased to a 12 to 20-mesh, and the powder was called J. 2 until 1875, when the name was changed to Rifle Fine Grain or R.F.G. These dogwood powders can be distinguished from the old F.G., not only by the size of the grain, but more readily by the charcoal being browner and the grain being rounder and not so flakey. The inner portion of dogwood is of a reddish brown color, and this color is imparted to the charcoal and thus to the powder. The roundness of the grain is due to the soft friable nature of the charcoal, dogwood being a small soft wood and easily charred.

It has always been found that powders made from dogwood are more violent than those made from alder or willow. Some have thought that this is due to the larger proportion of gaseous matter in the constitution of dogwood charcoal.

Dr. Percy, however, justly observes, I think, with regard to the presence of gaseous matter in charcoal as fuel, that, inasmuch as there is always an excess of hydrogen, over what is required to burn up all the oxygen, the latter must be regarded not only as water, but as water in the solid state or most disadvantageous condition, and its presence is therefore detrimental.

Dogwood being, as I have said, very readily charred, the process of charring is usually conducted at a low temperature; and wood charred at a low temperature always contains more oxygen

and hydrogen in its constitution than more highly burnt charcoal. But it by no means follows that the greater violence of explosion of the powder is due to the greater amount of gas in the charcoal. No doubt the gas in the charcoal aids the inflammability; but I think that the main reason is to be found in the fact that charcoal "burnt" at a high temperature is always harder, denser, and a better conductor of heat than when burnt at a low temperature. The conductivity of heat makes it withstand the action of the heated gases, I imagine, just in the same way as the well-known conductivity of heat in copper makes it the best material for resisting the action of fired gunpowder in the bore of a gun; and its hardness prevents it from being reduced to an impalpable dust so readily as slack-burnt or under-burnt charcoal. If the latter be crushed between the fingers it is easily reduced to a fine soft dust, while the former is hard and gritty. It is therefore, I think, because the particles of charcoal are smaller and more readily inflammable that dogwood powders, more especially when the charcoal has been burnt at a low temperature, are quicker than other powders. What appears to be required, therefore, in the manufacture of fine grain powders, is that the particles shall be as fine and as close together as possible, so that the combustion may proceed with sufficient rapidity.

The question, however, may be asked, cannot the slower burning of the alder or willow charcoal be compensated for by making the grains of powder finer? I shall answer this question by a short statement of the experience of Waltham Abbey on the point. I have already referred to the change from F.G. to E.R. powder, in which dogwood was introduced, and to the change from E.R. to J. 2 or R.F.G., in which the size of grain was increased; and I may add that in the most recent manufacture of this powder, the grain is somewhat larger than in the original manufacture, while in addition the density has been increased, a quality which has the same effects to a great extent as size of grain. And now, as far as we know, no powder excels R.F.G. in shooting qualities in the Enfield rifle.

When the Martini-Henry rifle was introduced, it was found that R.F.G. could not be used, because it fouled the rifle. What was the cause of the fouling it is difficult to say, unless it be that the density of the powder was too low and its action too quick, which would also account for the inferior shooting, if we suppose that the great pressure would crush up the bullet and thus interfere with its concentricity of spin and accuracy of flight. It is to be borne in mind that the bore of the M.H. rifle is small and the bullet long, which not only very much increases its inertia, but also gives less space for the powder to expand. Hardening the bullet has better enabled it to resist the greater strain which is thus produced, but the action I have described is occasionally to be observed in the drop-shots which sometimes occur with this rifle, which probably are the result of the bullets being exceptionally soft. The fouling might, therefore, be due to the great length of the cartridge interfering with its thorough ignition with so quick a powder, in the same way as wave action exists in guns, when the powder is not suitable. I can see no reason why this action should not take place with small arms as well as with large guns, and so part of the charge remain unconsumed: and this, I think, is no doubt one cause of fouling, though it is not the only one. The want of proper lubrication by the non-expansion of the beeswax wad, and the consequent escape of gas over the base of the bullet is another. Exceeding dryness of the air and want of softening of some of the products of combustion from deficiency of moisture is a third.

In support of the notion that wave-action is a cause of fouling, I may mention that a sportsman lately told me, that when he washed out the piece after firing a very fine powder, the water became as black as ink, but that this did not occur when a coarser powder was used.

Shortening the charge by chambering has simplified the problem of finding a suitable powder, but still it has been found that it is only by increasing the charge from 70 to 85 grains, and using a very slow burning powder, that satisfactory results are to be obtained.

The Committee on Breech-loading Small Arms, in their investigations as to the most suitable powder for the H.M.

rifle, found that Curtis and Harvey's No. 6 powder gave the best results. They naturally wished to obtain a similar powder from the Royal Gunpowder Factory.

In the opinion of the Superintendent at Waltham Abbey, such powder could be produced by making the following alterations in the manufacture of R.F.G.:

1st. Charcoal burnt at a lower temperature;

2d. The charge taken off the mill bed in a moister condition;

3d. Pressed to a higher density;

4th. More highly glazed and sifted to a more uniform size of grain.*

It would appear that the way to make the best powder is to prepare the materials with a view to make the powder as rapidly burning as possible, and then to moderate the combustion by density and size of grain. If the powder be not quick burning the density very much affects its rate of burning, and, as was seen with W.A. inch cubes of high density, the powder becomes much too slow for any gun. Now it will occur to most that, as soon as the pressure rises in the bore of the gun, the density of powder remaining to be burnt becomes very much increased; and, though the powder used be of low density and consequently quick burning on that account, it will soon become a slow-burning powder. This is the condition we most wish to avoid; and, therefore, it is better to start with as high a density as possible and have it naturally-quick burning, and thus the rate of combustion will be less affected when the pressure rises in the bore of the gun.

These conditions would, I believe, hold absolutely true were it not for another feature in the burning of grains of powder which accelerates the combustion of powders of lower density, though otherwise slower burning. I refer to the porosity of the grains, on which I more particularly dwelt in a previous paper read here. With the same density of grain, powders made with hard burnt charcoal are more porous than those made with slack burnt charcoal, because, the particles of charcoal being coarser, the spaces between will be proportionately larger; and also the particles of charcoal, being denser, will occupy less space, and so leave more room for interstices. The crushing pressure of these particles also we may suppose to be higher than with soft charcoal, which will enable them to build themselves up in accidental positions, and thus give rise to uneven densities in different portions of the grain itself. Under the intense pressure in the bore of the gun the flame becomes forced into these spaces, and the less dense portions of the grain burn more rapidly than the harder portions, and thus give rise to that particular pitted and burrowed appearance of unconsumed grains of powder which are picked up after the discharge of the gun, with which we are all familiar. It is difficult to say how far the flame becomes forced into these channels, but the effect must be that from each small center of penetration the combustion proceeds more rapidly as larger and larger surfaces come under ignition, and so an increased amount of gas is generated. It is a great mistake to assume that under all circumstances the combustion proceeds in regular successive laminæ from the surface to the center of a grain of powder. With very high densities 1.82 to 1.84, when the powder probably has been subjected to a pressure equal to the crushing strain of the particles, I believe no appreciable interstices exist, and then the grain does burn regularly from surface to center. The rate of burning then depends on the fineness of the particles of charcoal, each particle requiring to be consumed before the flame can reach the next to ignite it; and this no doubt accounts for the very marked difference in burning of W.A. 1″ cubes of ordinary charcoal, and Hall and Sons 1″ cubes of dogwood charcoal. With lower densities, however, the conditions are different, and though the slack burnt charcoal still retains its greater rate of combustion, yet the greater certainty of porous channels, or unequal densities in the grains with harder charcoal enable it with more certainty to take advantage of the accelerated rate of combustion I have noted, and so tend to a great extent to reduce the difference in ultimate effect. It is mainly, in my opinion, due to this fact, that our cubical powder is able to match to so great an extent the prismatic

* Tabulated results of many experiments with powder of different brands were given in the original paper, but for want of space the writer's conclusions only are presented here.

powder used by some foreign governments.

In the prismatic powders the channels are introduced into the grains of powder intentionally, so that there may be an accelerated rate of burning from them as centers as the combustion proceeds. The manner in which these holes are made, however, renders it uncertain whether their whole surfaces are ignited, as we find with pressed surfaces that they are generally only ignited from points; and, in fact, portions of grains of powder are often picked up of which the surface never appears to have been ignited. If the holes could be bored so as to give more readily ignitable surfaces, it is probable that the combustion would be much improved. Prismatic powder has to be made of much lower density than granulated or broken powder, in order to compensate for the greater difficulty of ignition.

It will be observed with prismatic powder that the sizes of the prisms are of no consequence provided that the channels are proportionately numerous and suitably placed. And in support of this notion I have advanced that our powders are porous, I will give the following results obtained by experiment with powders of different sizes of grain with the same density. The powders were pressed in the same press-box at the same time, so it is tolerably certain that their densities were identical.

Powder.	Density.	In 8-in. gun, 35 lbs. charge, 180 lbs. projectile.				
		Muzzle Velocity.	Pressure.			Length of Cartridges.
			A	B	C	
W.A. Sept. 30, 1875. Rework		f. s.	Tons.	Tons.	Tons.	
1.5 inch cubes	1.76	1,471	16.2	15.5	15.1	$20\frac{1}{4}''$
1.7 inch cubes	"	1,471	16.8	16.1	14.1	$20\frac{1}{2}''$
2.0 inch cubes	"	1,452	15.7	15.2	15.2	$21''$

If we make allowance for difference in lengths of cartridge, these three samples give almost identical results in the 8-inch gun; and when we come to the 38-ton gun the larger cubes by no means show to advantage:

Powder.	Density.	In 38-ton gun, charge 130 lbs., projectile 800 lbs.			
		Muzzle Velocity.	Pressure.		
			A	1	2
W.A. September 30, 1875. Rework		f. s.	Tons.	Tons.	Tons.
1.5 inch cubes	1.76	1,460	26.1	27.7	19.7
1.7 inch cubes	"	1,440	27.3	26.5	24.5
2.0 inch cubes	"	1,409	28.7	24.5	22.5

Description.	Density.	38-ton gun.			
		Muzzle Velocity.	Pressure.		
			A	1	2
W.A. December 2, 1875. Rework		f. s.	Tons.	Tons.	Tons.
1.5 inch cubes	1.81	1,396	22.2	22.2	21.2
1.7 inch cubes	"	1,330	17.6	17.0	17.2
2.6 inch cubes	"	1,350	15.0	13.7	15.2

Take, however, the following samples of powders of equal but higher densities, and the effect of size of grain is very marked :

(*See last Table on preceding page.*)

Both of these sets of samples were made from rework L.G., with the same description of slack burnt charcoal. I have already compared the latter 1-7 and 2-inch specimens with those of W.A., February 5th, 1876, of lower density made from new materials where the charcoal is more burnt. It will be observed that, with the February 5th, 1876, specimens, the pressures do not go by size of grain, showing that the powder is porous owing to the low density; and, as already stated, though the velocities are about the same as in the last samples given, the pressures are higher, which bears out my theory about the higher densities and quicker burning materials giving the best results.

Of course I do not give these samples as *proving* the question, but merely as illustrations of the features I wish to bring before you. We have had samples, especially those made by Messrs. Hall and Sons, of Faversham, of powders of low densities and hard-burnt charcoal which have given the very best results. They have been tried, however, with powders only 1″ cubes, and density 1-75, giving results too quick for the 38-ton gun with large charges.

This leads me to the consideration of the third and last feature I wish to lay before you. I believe the action in that case to be modified by the slow burning of the particles of charcoal themselves, these particles being so large and dense that, if we suppose an extreme case, all the particles may be ignited very rapidly, but the mean time of burning of the charge depends on the burning of a single particle. Charcoal has never been burnt at Waltham Abbey to an extent so as to produce this result, so that I am unable to give any accurate data as to how far this method may be carried out on a large scale. But I think it is worth investigation.

I may now sum the different features in powders for large guns, by which the rate of burning may be modified.

1. A quick burning powder, with a high density, and no appreciable porosity.

2. A moderate burning powder, with a moderate density, leaving moderate porosity.

3. A very slow burning powder, with very large porosity.

Powder may be produced to give very good, and possibly equally good, results, by any of these methods, but, I think, probably it can be produced best and with greatest certainty by the first method. It is, however, by far the most expensive, owing to the greater time required to manufacture.

The second method, with a slight tendency towards the first, is that by which powders have hitherto been made at Waltham Abbey. It is the cheapest, but it depends to a great extent on the most uncertain of all the qualities, viz., porosity. The only means by which this uncertainty can be neutralized is by systematic proof and careful mixing. When this is properly carried out, the results can be relied on with perfect certainty.

In all cases size of grain is a most important element which can never be dispensed with, owing to the facility which it gives for the complete ignition of the charge, and the total elimination of wave action, which is so very destructive to the bore of the gun. From observation of the good results which were obtained by Hall's inch cubes in the 8-inch gun, I was led to suggest the trial of 2-inch cubes for the biggest guns, for, if we double the diameter of the bore of the gun, we ought also to double the length of the side of the cube of powder required for it. With such large grains no wave-action is now to be observed even if the charge be ignited in rear. It is, therefore, a safe and sound principle to keep the grains as large as possible, provided other qualifications are not unnecessarily sacrificed. Were, however, our heavy guns breech-loading, the result of my observations lead me to believe that, if the cartridge were ignited along the whole centre from the rear, smaller grain and denser powder could be safely used, and greater efficiency thus obtained.

I may mention a difficulty which has been encountered in the manufacture of these large cubes. In glazing in the ordinary manner, it has been found that the amount of heat generated is not sufficient to make the powder sweat in

the glazing barrels. The portions thus rubbed off are not pasty enough to adhere to the sides of the barrel, but remain in a state of dust, which adheres to the cubes, and requires to be removed before the powder is finished and black-leaded. It is anticipated that, by using one large instead of four small glazing barrels, not only will this objection be removed, but larger units will be obtained for the after process of mixing. The system of mixing, and proof of pebble-powder, I have explained in a previous paper. It is obvious that if a sample of 130 lbs. of cubical powder be fired from each batch, the batches must be large to prevent an unnecessary expenditure of powder. By adopting a unit of 1,600 lbs. instead of 400, as in the case of pebble-powder, a batch of 16 times 1,600 lbs. can be obtained if four ordinary stovings be reserved before the powder is finished. For this purpose a finishing reel, to contain 1,600 lbs., has also been made. Cubical powder will not pass through a hopper in the same way as pebble-powder, because the grains are so large, but, by means of this mixer, it is anticipated that, if required, as many as 16 different batches can be made uniform, by taking a barrel from each for a run.

I trust that the remarks which I have now submitted to you, will show how deeply interesting and important this subject is, and how steadily and surely light has dawned on us, with the aid of the proof tests, which were inaugurated and carried out by the Committee on Explosives. I have had the opportunity of studying the matter for now nearly five years, during perhaps the most interesting period; and I hope it may not be considered inappropriate to have laid the results of my observations before you. Though many of the deductions I have drawn are merely my own theories, they are the fruit of long and careful study, and they will not, I feel confident, be lost sight of by those who have to do with powder at Waltham Abbey, or elsewhere.

HYGIENIC STUDIES ON THE ABSORBING POWER OF SOILS.

By Dr. LISSAUER.

From "Deutsche Vierteljahrsschrift," through Proceedings of Institution of Civil Engineers.

In experiments hitherto carried out in connection with this subject, the samples have been taken by simply digging them from the ground with a spade, a plan which does not permit of the soil being examined in its natural state; and it is clear that its absorbing power mainly depends upon the relative position of the particles of earth to one another. To overcome this difficulty the author used a tin cylinder, encircled by an iron case made in two halves, so that it might easily be removed, and furnished with a circular steel knife at one extremity and a stout handle at the other. By thrusting this apparatus into the ground, and then withdrawing it by means of the handle, the cylinder could be filled with a sample of soil in its natural condition. By then removing the iron case and fastening a perforated cap to the lower end of the cylinder, it was possible to filter liquids through the sample without in any way disturbing it.

The results of fifty-one experiments made with this apparatus point to the following conclusions:

1. The liquid entering the pores of the soil displaces the air or liquid previously present, forcing the former upwards into the atmosphere, and the latter downwards into the subsoil or effluent water.

2. In order that the effluent water may not be directly polluted by the sewage liquid, the maximum supply of the latter must not be more than can be taken up by the pores of the soil.

3. Dry loamy soil absorbs more than peaty soil and gives up less, whilst dry sandy soil on the contrary absorbs less and gives up more. Consequently a loamy soil, though it absorbs a large quantity of liquid, can seldom be irri-

gated; whereas a sandy soil, though it absorb but little, may often be irrigated.

4. The looser the soil the easier water-courses are formed in it, and therefore the less can its maximum power of absorption be approached, otherwise the sewage liquid might penetrate the subsoil before the whole of the ground had been saturated.

5. In order, therefore, that the effluent water may be protected from pollution, it is especially necessary that the absorptive power of the soil should be known; but the determination is of no value unless it be made in a sample in which the natural position of the particles of earth have been undisturbed.

6. Having determined how much fluid a cubic yard of the soil can take up, and therefore how much is necessary for the daily supply of sewage liquid, this is to be multiplied by the number of days which must elapse before the organic matters present in the liquid shall have been destroyed. As a criterion of this, it is sufficient to ascertain if after all free ammonia has been expelled, any more is formed on burning with soda-lime; but in making use of this test of course any nitrates or nitrites that may be present must be taken into account. This period of time should be determined by special experiments at different times of the year and under different systems of cultivation.

7. The presence of such non-nitrogenous organic acids as arise from regressive metamorphosis cannot serve as an indication of the impurity of the effluent liquid, since when once formed they remain unchanged for a long time.

8. Having determined the cubic amount of earth which is necessary for the available supply of sewage liquid, some means must be taken to guard against the fluctuations of the effluent water by drainage. It is therefore recommended to add at least ½ yard to the depth as reserve soil, for the protection of the effluent water from such accidental disturbances as rain or the formation of water-courses.

9. Suspended matters only then pass through the soil when, like Bacteria and Monads, they are smaller than its interstices and specifically lighter than the sewage liquid.

10. The suspended matters which are specifically heavier than the sewage liquid are retained by the soil, making it closer and increasing its power of absorption.

11. The absorptive power of a soil depends upon its character, and also to a great extent upon the degree of concentration of the liquid used. Unless, therefore, the determinations are made with solutions of equal strength, they lead to false conclusions.

12. As the result of four years' irrigation at Heubude, the absorptive power of the soil has been more than doubled.

13. The absorptive power of a soil for urea is very much increased by vegetation; but however high it may be, the soil never withdraws the whole of the urea from a liquid; some of it always remains in solution.

14. The effluent water of an irrigation works ought not to be compared with good drinking water, since it must nearly always contain some ammonia; often nitrates and nitrites, and always a certain amount of chlorine, which is almost completely unabsorbed by the soil.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—Among the valuable papers recently presented to the Society are: Reconstruction and Enlargement of Cork Run Tunnel, on the Pittsburgh, Cincinnati and St. Louis Railway, M. J. Becker; Notes on the Masonry of the East River Bridge, F. Collingwood; The Rate of Set of Metals subjected to Strain for considerable Periods of Time, R. H. Thurston; Co-ordinate Surveying, H. F. Walling.

THE AMERICAN INSTITUTE OF MINING ENGINEERS.—The last volume of the transactions is full of the most valuable matter.

It may safely be put in competition with similar journals anywhere in the world for the first place. We reproduce from it in the present number of this magazine, an article by Prof. J. C. Smock.

The semi-annual meeting is about to begin its session in this city, and more valuable additions to the science of mining metallurgy may confidently be expected.

IRON AND STEEL NOTES.

MR. ATTWOOD'S PATENT FOR MANUFACTURING STEEL.—The Judicial Committee of the Privy Council have granted an extension of Mr. Charles Attwood's patent for "improvements in the production of steel and iron of a steely quality," as owing to the peculiar character of the trade the patentee and his representatives had not been reimbursed for the great expenditure of time and money which

had been necessary. The late Mr. Attwood took out his patents in 1862 in several countries, and it was submitted to the Court that before that time steel had been made by the cementation process, which was a costly one, and also of long duration. Mr. Attwood's method, however, altered this, for steel of any desired quality could be produced in a few hours by one operation. To carry out the process, Mr. Attwood erected works at Towlaw, at considerable expense and trouble, but they were profitless, and had to be dismantled in 1863. At Wolsingham afterwards he laid down another establishment, and though he sold a large quantity of steel, the great expense of developing the process made it a source of loss. Since 1872, it had, however, realized a profit. It was this year beginning to reap a fair reward. Mr. Wm. Baker, of Sheffield, and others, bore witness as to the value of the invention.

MR. BELL'S IMPROVEMENTS IN THE MANUFACTURE OF IRON.—The particulars of this invention have been published by the Patent Office, from which it appears that he proposes to make puddled iron from pig iron formerly unsuited for it. He says it has hitherto been found impracticable to obtain a malleable product in the Bessemer converter, or from Siemens-Martin furnaces from certain qualities of pig iron, and he takes such iron as it comes from the converter or furnace, adding to it spiegel iron, and transferring it into a puddling furnace, where it is worked either by manual labor or mechanical means. The following statement by Mr. Bell, explains exactly how he proposes to proceed:

In the substitution of mechanical for hand puddling in furnaces known as rotary, considerable difficulty has been experienced in preserving, from the action of the heat, the lining which serves among other purposes as a protection to the iron casing of the structure itself. In a great measure, I believe this action to be due to the presence of silicon in the pig iron under treatment, which, being oxidised during the operation, attacks the oxides of iron constituting the lining in question.

My process consists in submitting crude iron intended to be used in such furnaces as those described, by preference from the blast furnaces direct to the action of a current or currents of air. This is easily effected in a piece of apparatus known as the Bessemer converter. The extent of which this operation has to be carried will depend on the quantity of silicon contained in the pig iron. When this amounts from 1½ to 2 per cent., I find five minutes' exposure to a blast of 15 to 20 lbs. on the square inch will suffice.

When the metal has been blown to the extent desired the metal is passed, by preference it is run direct into the rotary puddling furnace, and puddled.

In place of stopping the blowing operation whilst the iron still contains sufficient carbon for puddling, the blowing may be carried further, and the carbon afterwards replaced by adding spiegel iron or other pure cast iron rich in carbon; this, however, adds somewhat to the cost of the process.

It often happens that the relative quantities of silicon and phosphorus in pig iron are such that, before the former can be sufficiently oxidised, the carbon it contains is burnt off to an extent which interferes with the subsequent operation of puddling. In such a case, the iron in the puddling furnace comes to nature, as it is termed, before the phosphorus is properly acidified and removed by the oxide of iron always present. When, therefore, it is desired to obtain malleable iron as free as possible from phosphorus, I find it useful to prevent the too rapid expulsion of the carbon by blowing into the converter, along with the blast, carbonaceous matter, such as ground coke, charcoal, or other similar substance; or, as already explained, the carbon may, after blowing, be replaced by adding spiegel iron or other pure cast iron rich in carbon. On the other hand, where malleable iron of a hard character is required, I continue the blast until more or less of the carbon of the pig iron is expelled, by which means the metal retains more or less phosphorus, which imparts to it the property of hardness or cold-shortness, as it is termed.—*Journal of Iron and Steel Institute.*

RAILWAY NOTES.

TURKISH RAILWAYS.—The last two great wars on the Continent have sufficiently demonstrated the great value of railways for operations in the field. On that account it will be interesting to note the railway resources of the Balkan Peninsula, which may at once be said to be greatly deficient in this respect. There are no lines of railroad at the seat of war and in its immediate neighborhood, and thus the removal of troops from one scene of operations to another, depends entirely on the marching powers of the troops engaged, which, as we know, up to the Crimean War always regulated their movements. Turkey for the first time now uses the few railways at her disposal for transporting her forces from distant provinces. Since the extent and importance of those several lines are not generally understood, it may not be out of place to enumerate the few railway communications at the disposal of the Turkish commanders. There are five railway routes in European Turkey, all independent of each other, and having no junctions with foreign railway systems, with the exception, perhaps, of the line from Varna to Rustchuk, joining here the Roumanian system of railways. The most eastern and shortest of Turkish lines leads from Kustendje, on the Black Sea, to Tchernavoda, on the Danube; the second from Varna, on the Black Sea, past Schumla over Rasgrad to Rustchuk on the Danube, where it joins the Roumanian railways. The third and longest line, the Roumelian Railway, leads from Constantinople over Adrianople and Philippopoli to Sarembey, there branching off along the Maritza to Dede-Aghatch, on the Ægean Sea, and is intended to be extended beyond Sofia. The fourth line, which, besides the last-named, has lately been most used for the transport of troops, starts from Salonica, and ends at

present at Mitrovitza, but is destined to form the connecting link with Hungary and Austria, and thus to become the most convenient and direct line of communication of the East with the West. The most simple network of railways will only be completed when the Roumelian Railway is joined to the Salonica-Mitrovitza line, and the latter to the Austro-Hungarian railway systems. Only then will this line, which will afford uninterrupted communication between Paris and Vienna and Constantinople, become of importance. The reason why this undertaking has not yet seen its completion is found in the miserable quarrels of the Turkish Government with Baron Hirsch, the railway contractor. The line of junction most easily to be constructed would lead through Servia, while Turkey wishes to see the railway continued through her territory, namely, the Herzegovina and Bosnia, although those countries must offer the greatest difficulties to railway construction on account of their extremely mountainous nature and sparse population. The Turkish Government has constructed already a short line in Bosnia, the fifth in our list, leading from Doberlin over Novi and Priedor to Banyaluka, destined to form an intermediate link between the Roumelian and Austro-Hungarian railways. Servia does not possess a single line of railway; and only one Hungarian line, that from Temesvar to Bazias, has its terminus on the opposite bank of the Danube; Belgrade itself being still dependent on stage-coach and river communications. The construction of Servian railways was, however, almost as good as secured, and had not the war intervened, would have commenced in a few months. Roumania has an extensive system of railways, nowhere, however, on account of the intervening Carpathian Mountains, joining the Hungarian railroads. Greece has at present only one short line, the railway from Athens to the Piræus; and it need hardly be mentioned that Montenegro has no railways, and probably never will possess any.

A Railway in China.—The Celestial Empire has at length become the scene of railway operations, and, although only on a small scale at present, it leads to the hope that the present may prove the precursor of many lines. The question has been agitated for some years past, the Chinese proving very difficult to be persuaded of the advantages of the railway system. In 1873 it was proposed to subscribe for a short line of railway which was to be made and presented to his Majesty the Emperor. The scheme was well supported here, and was warmly discussed when the Iron and Steel Institute visited Liége in 1873. At that time Mr. R. C. Rapier, of the firm of Ransomes and Rapier, of Westminster and Ipswich, had a special audience of the King of the Belgians upon the subject, and the leading members of the English and Belgian iron trades gave their adhesion to the project. But it fell through on account of political reasons which interfered to prevent the consummation of the plans. There were, however, some gentlemen who were moving in another direction at the same time, and with the same object—that of introducing railways into China. These were Messrs. Jardine, Matheson, and Co., of London and Shanghae, who, with their friends in both countries, had purchased land for a carriage road from Shanghae to Woosung. The notion of a railway, of course, soon occurred to them, and they had estimates made for a line between those points, which are 10 miles apart. The estimates however were high, and as there was a risk attending the investment, the project of an expensive railway was abandoned.

So far Messrs. Jardine's scheme. Messrs. Ransomes and Rapier still clung to to the belief that an opportunity would offer for the introduction of railways in China, and they constructed a small locomotive—the Pioneer—which they intended to send over, when practicable, to demonstrate the feasibility of a locomotive railway. The opportunity in time offered for placing it upon Messrs. Jardine's proposed line, and it was forthwith sent to China. That arrangement having been settled, Mr. Rapier prepared the estimates for a cheap line of railway with a 2 ft. 6 in. gauge, and a station at Kangwan, a point midway between the two termini. The estimate was £30,000 and the contract was let to Mr. John Dixon, of London. The line was commenced in January 1876, and has been constructed from Shanghae to Kangwan—half its length—and thus far it was opened on the 30th June last. The remainder of the line is well advanced, and is expected to be opened in a short time. The line was easy to make, being unattended with any engineering difficulties whatever. It is laid with 27 lb. rails of the Vignoles section, on cross sleepers. The little engine Pioneer was specially built to be the smallest practicable engine to travel 20 miles an hour or to haul 20 tons. The cylinders are 5 in. diameter with a 6 in. stroke. The engine is carried on four wheels 18 in. in diameter, all coupled and all fitted with brakes, the wheel base being 2 ft. 6 in. It has 35 square feet of heating surface and 1 square foot of grate area, and its weight in working order is 30 cwt. This engine has most completely succeeded in effecting its intended purpose, that of disarming the prejudices of the Chinese, the engine performing really appreciable work, and yet being so small as to cause any opposition to appear quite ridiculous. This primary difficulty was overcome during March and April last, and the larger-sized engines for working the line arrived out in May last, ready for the opening.

These latter engines are two in number, and have been respectively named the Celestial Empire and the Flowery Land. These locomotives were designed by Messrs. Ransomes and Rapier, by whom they were also manufactured. The type of engine was determined on to suit the local circumstances of the line, high speed being of less consequence than good hauling power. The length of wheel base is 7 ft. 6 in., and the wheels, 2 ft. 3 in. in diameter, are six in number, all coupled and fitted with brakes. The cylinders are 8 in. diameter by 10 in. stroke. The barrel of the boiler is 2 ft. diameter, the tubes being $1\frac{3}{4}$ in. diameter and 6 ft. long. The total heating surface is

150 square feet, and the grate area 4 square feet, the weight in working order being 9 tons. The water is carried in side tanks. The boiler and frame are throughout of Low Moor iron, and the boiler is constructed for a working pressure of 200 lbs., but it is intended to be used only up to 120 lbs. This excess of strength of the boiler is to meet any contingencies that may arise at the hands of the Chinese firemen. The railway is fitted with double water-supply tanks at each end of the line, so as to allow the water in all cases one day to settle. In order to fully cover the liability of being short of clean water, the water tanks of the engines are made large enough to run two double trips. Before being sent away these engines were fully tested at Ipswich to four times the maximum duty which they are ever likely to be called upon to perform in China. The trips which these engines have to run being short, the fire will often be brightest at the end of the journey, and the stoppages being long, the engines are provided with extra steam space by having both a high-topped fire box and a dome, and are also furnished with an extra large Gifford's injector, so as to fill up the boiler quickly when standing. The feed-pump is also of extra size. The frames are $\frac{3}{4}$ in. thick, and planed all over, the axle-box guides being of wrought iron and rivetted on to the frame. The springs are hung underneath the axle-boxes. The wheels have steel tyres and Low Moor axles. The engines are fitted with all the usual appliances, and have throughout been made with special care, having regard to their important destination. The carriages are first, second, and third-class, of substantial construction and plain but neat appearance.

ENGINEERING STRUCTURES.

The Water Supply of Lyons.—Previous to 1854 Lyons was supplied by water pumped direct from the Rhone and from private wells; about 55,000 gallons daily being drawn from the former source. As the supply was quite insufficient it was determined at the above date to seek, by the advice and under the direction of M. A. Dumont, an engineer of the Ponts et Chaussées, an increased amount by driving in the water-bearing gravel bed, which fills the center of the valley of the Rhone, and upon which the lower portions of the town are built, filtering galleries and reservoirs, whence the water might be pumped for distribution to the different quarters. A covered filtering gallery about 130 yards long, and a little over 16 feet wide, was then driven near the town on the right bank of the Rhone; it was built with solid sides admitting water only upwards through the floor, which was placed at 10 feet below the standard average low water mark of the river. A filtering basin was connected with this gallery to catch the water coming from it, 144 feet long by 125 feet wide, with the sides pitched and slopes of 1 to 1; it was arched over in spans of 14 feet 9 inches in the clear. Several similar filtering galleries and basins were added later on, as the demand for the water increased, till about 7,700 square yards of effective filtering surface was obtained. It was anticipated that this would yield during twenty-four hours about 9,000,000 gallons, or at the rate of about 1,200 gallons per square yard of filtering surface: however, it was found that when the river was low it was with difficulty that 6,500,000 gallons were obtained. Of late years the population of the town and the area supplied with water have increased very rapidly; and it became a question of much moment how to meet the augmented demand. On examination it was found, that, owing to the level of the invert of the filtering galleries, and to the existence of hard beds of conglomerate around them, no very greatly increased supply could be expected even from a very much larger filtering surface of galleries. It was, however, ascertained that underneath, below the conglomerate beds, there existed a fine, porous, bed of gravel; and it was finally decided to sink down a number of wells from the floor of the filtering galleries into this water-bearing strata. During the course of last year seven of these, 6 feet 6 inches inside and 26 feet deep, were sunk; they are octagon shaped and lined with cast iron framing. These wells have given very satisfactory results, yielding nearly 400,000 gallons each during twenty-four hours. With their aid there is no difficulty in affording the present average daily supply of nine million gallons, or about $25\frac{3}{4}$ gallons per head; and also, it is anticipitated, in meeting further demands. The distribution of this water to the town of Lyons, built at very great difference of level and extending over an area of 11,000 acres, was a matter of some difficulty. For this purpose Lyons is divided into four districts: (1) the low level; (2) the high level; (3) the heights of Fourviere; and (4) the park on the other side of the Rhone. The low level service has four pumping engines, three of them Cornish, of 170-horse power each, with steam cylinders 3 feet 3 inches in diameter, and 8 feet 2 inches stroke; the remaining engine being double-acting, of 135-horse power. In case of need these engines, if working together, can raise 17,000,000 gallons in twenty-four hours; they deliver into a service reservoir at Magnoles at about 160 feet above the filtering well. The high level district has two direct-acting engines of 135-horse power each, which deliver into a reservoir at Montessuy, 315 feet above the well. The heights of Fourviere have a reservoir 197 feet higher than the last, or 512 feet above the filtering well, with a small 30-horse power engine to supply it. The detached service of the Park is performed by a 35-horse power engine pumping into a reservoir 118 feet above the low water level of the station. The water supplied is soft, clear, and of excellent quality; it is alkaline and also rich in carbonic acid; its average temperature at the well is 63 deg. Fah.

Wire Tramways.—Notwithstanding the general dulness which has for some time past pervaded almost every department of trade, both at home and abroad, there are a few branches of business in which more or less briskness is apparent. These are mostly cases of perfecting plant and appliances designed for use in the revival hoped for, with some reason,

as likely to come before long. Noteworthy among them is the fitting up in many quarters of Hodgson's useful system of light goods carriage by means of a "wire tramway," as carried out by Mr. Carrington, which, we are informed, has been steadily extending itself in all parts of the world. Several hundreds of miles are now in operation, a considerable portion of which has been erected during the last two years. Many improvements, lately invented, have been introduced, consisting chiefly in the minor working details, which, though insignificant in themselves, have largely contributed, in conjunction with the especial care taken in the manufacture of the plant, to the very successful results which the more recent tramways have given. One improvement, which has had the effect of greatly extending the application of the system, consists in the use of a peculiarly-formed grip, by means of which the loads can be made to adhere to the wire rope to such an extent as to ascend or descend inclines as steep as one in three without slipping. It will at once be seen how, with such capabilities, the tramways, instead of taking circuitious routes in order to obtain an incline of not more than one in six, the original limit, can now be laid in a direct line, passing up the sides of hills which otherwise would prove impracticable. In cases where ravines occur, too wide to allow of the ropes being stretched across in the usual way, the tramway can now descend the sides. A good example of a wire tramway working on a steep incline may now be seen daily at work at the flannel works of Messrs. Butterworth & Co, near Rochdale, where it is employed to carry coal from the mine situated at an elevation of about 500 feet. The line is laid direct from the mouth of the mine to the boilers of the factory, and is about 500 yards in length, thus descending at the rate of about one in three. The coal is carried in loads of one and a half cwt. in wooden boxes, and, owing to the great incline, no power is required to keep the rope in motion. A quantity of five tons per hour is transported, and only the labor of two men is required. Similar lines are in operation at the works of Messrs. Norton Brothers (limited), near Huddersfield, where the tramway in its course passes over a great part of the works, and carries the coal direct from the pit mouth to the boilers, it being filled from the pit corves into the tramway buckets by means of a hopper and a slide, which enables one man to do all the work required. This tramway derives its power from the mill shafting. Another useful application has been made at the sugar works of James Duncan, Esq., for the purpose of carrying coal from the side of the Thames, where it is brought in barges, to the interior of the works, a distance of about 150 yards—throughout its course it passes over the various buildings and roadways, which are now left free for the regular traffic of the works—the cost of carriage of the coal at these works has been greatly reduced by the use of this tramway.

Ano her and very valuable application of the system has been for the construction of a cheap means of shipping or unshipping ma'erials at a distance from the shore, where the length is too great to admit of the erection of a pier. The tramway terminal, in such cases, is attached to a group of piles placed in deep water, and the ropes are supported on wood posts placed at intervals of about sixty yards between the terminal and the shore—thus practically forming a pier without the great expense of a continuous platform. Advantage may be taken, in such cases, to transmit power from an engine situated on the shore to the pier-head or sea terminal by means of the wire-rope, which, at the same time, can also be carrying the loads from the shore to the ships, or *vice versa*. Cranes on the sea terminal can thus be erected for unloading by means of the power placed on the shore—a great desideratum when the power is available from a factory, or is used for other purposes, or where the roughness of the sea renders it unwise to put a costly engine and boiler at such an exposed place as the sea terminal would be.

An example of such a tramway is in operation at the mines of the New Zealand Manganese Company, where it carries the ore from the mines about half a mile inland, and at an elevation of about 250 feet to a sea terminus situated 1,200 yards distant from the shore, in a depth of fifteen feet of water. This terminal is made out of the hulk of an old steamer, securely moored in position, and between it and the shore about twenty posts are placed, which support the ropes and buckets as they travel from the mine to the ships. This tramway has been in operation for some time, and has greatly reduced the cost of carriage and shipment. Another tramway of a similar nature is now in course of erection at St. Vincent, in the Cape de Verde Islands, for the coaling depot of Messrs. Cory Brothers, of Cardiff. Wire tramways are also now extensively used for sugar-cane estates, where they present some special advantages not possessed by any other system of transport. To these and many other special applications of the system we may refer in a future number.

ORDNANCE AND NAVAL.

THE NEW AUSTRIAN IRONCLAD TEGETHOFF. —A brief summary of the characteristics of this important ship, now under construction at Trieste, as the latest embodiment of Austrian naval opinion, will be interesting to our readers. We may mention that she is, in a peculiar degree, the embodiment of naval opinion in Austria, inasmuch as her design is the consequence of the prolonged inquiries and deliberations of a very carefully selected Committee which sat for several months at Trieste, although Herr Romako, the Chief Constructor of the Vienna Admiralty, is no doubt personally responsible for the technical details, and for the calculations of the ship. In a paper presented to the Institution of Naval Architects a few weeks ago, Mr. Reed gave the following general dimensions and particulars of her: "Length between the perpendiculars, 286 feet 11½ inches; length, total, 303 feet 1½ inches; breadth on the water line, 62 feet 9 inches; extreme breadth to outside of armor, 71 feet 1½

inch; depth of hold, 34 feet 9 inches; draught of water, aft, 26 feet 7½ inches; draught of water forward, 23 feet 1 inch; displacement with the half of provisions, 7,390 tons; area of the midship section, 1,301 square feet; area of the load water-line, 14,308 square feet; height of metacentre above centre of gravity of displacement, 14.623 feet; height of metacentre above water, 4.770 feet; distance of the centre of gravity of displacement before the midship section, 0.356 feet; depth of the centre of gravity of displacement below water, 9.853 feet; co-efficient of displacement, 0.582 feet; co-efficient of water-line, 0.782 feet; co-efficient of midship section, 0.82 feet; displacement of an inch immersion at the load water-line, 34.47 tons; weight of armor and backing, 2,160 tons; the armament consists of six 11 inch Krupp guns. Area of sails 12,165 square feet; cost of hull, estimated, £172,790; cost of engines and boilers, estimated, £81,715; nominal horse power, 1,200; number of cylinders, 2; diameter of cylinder effective, 125 inches; length of stroke 4 feet 3 inches; Griffiths propeller, diameter, 23 feet 6 inches; pitch, 24 feet; number of blades, 2; revolutions per minute, 70; number of boilers, 4; area of fire-grate, 850 square feet; heating surface, 25,500 square feet; superheating surface, 1,800 square feet; pressure of steam, 30 lbs.; number of furnaces, 36; mean indicated horse-power, 8,000; speed, estimated, 14 knots. From these figures it will be seen that although we are not dealing with a ship of the Inflexible (English) or of the Dandolo (Italian) type, in which armor of excessive thickness is placed over a central citadel of extremely limited extent, we nevertheless have a very powerful ship indeed, with armor of apparently about 13 to 14 inches thick, and with a concentrated battery of six 11 inch Krupp guns, each weighing, I presume, about 27 tons. The ship has a belt of armor extending from the stern to within about 30 feet of the foremost perpendicular, where it terminates in a transverse armored bulkhead, and a stout iron deck going forward to the stem at about 7 feet below water." The Tegethoff has a long projecting under-water spur—it projects 9 feet from the stem at the load water-line, and 19 feet from the stem-head. Nearly all double curvature is excluded from the armor plates The battery is of the projecting type adopted by Mr. Reed in the upper decks of the Audacious class, and on the main decks of the German and Chilian iron-clads designed by him. The battery is traversed by a bulkhead which cuts off the two foremost battery guns from the remainder, after the plan adopted by Mr. Barnaby, in the Alexandra. The ports are thrown back from the outside of the side, as explained in a previous paragraph.

KRUPP'S ARMORED GUN.—"The future belongs to iron," is the dictum of engineer officers, when speaking of the principal which will have to guide them in the construction of new fortifications. The solution of the question of iron armor, however, seemed yet to lie in the distant future, until it has suddenly been brought into prominence by the latest invention of Krupp—an armored gun. The models of this piece of ordnance, according to the *Cologne Gazette*, have been submitted to the German War Office, our contemporary expressing the opinion that, considering the simplicity and evident usefulness of the system, it will be introduced in Germany. The problem which has awaited solution for years, but which has hitherto not been satisfactorily solved, the removal of the recoil of heavy guns, seems at last to have been finally settled for seige, coast, and naval guns. The gun, when fired, remains fixed in its original position, without necessitating a complicated carriage. As the name indicates, we have to do here with an intimate connexion of armor and gun. A sphere is screwed round the muzzle of the gun, any piece of ordnance being easily adapted to it, fitting exactly into the socket joint of a fixed armor plate. The trunnion of the gun rests in a simple iron carriage provided with rollers running on circular rails. These rails, in connection with the socket joint, permit of the requisite lateral pointing of the gun. The thickness of the armor ought to correspond to the calibre of the gun.

At first, many theoretical objections offered themselves to the plan, the inventor of which is Herr Krupp himself. It was predicted that the sphere would be torn off, the gun would burst, the armor plate would be injured. The practical trial has given quite an opposite result. Although it is the intention of the inventor of fixing in this manner heavy seige guns, experiments have as yet been made only with the German 8.7-centimetre (3½ inch) field gun. No less than 203 rounds were fired with a powder charge of 3 lbs. 5 oz., and a projectile weighing 15 lbs., without the armor plate or the barrel of the gun showing the slightest injury. Even the thread, exposed to so much strain, holding together the sphere and the muzzle, had not suffered. The sphere could be screwed off as easily after the firing as before commencing it.

The most important advantage of the new construction consists in the gun remaining in the same fixed position throughout the firing. If once pointed, relaying at each shot is entirely dispensed with, and it consequently permits a rapidity of fire not to be attained with other guns. In firing sixty rounds in fifteen minutes, a remarkable and highly satisfactory result was obtained. The target showed that it had been hit by the sixty shots within a narrow compass on its left side, although the distance was 1,663 yards, and the gun had only been once pointed at the beginning of the experiments, the firing having been continued to the end without once stopping for relaying. The minutes of the trial were signed by a number of foreign officers present, who expressed their surprise openly, at the unparalleled results obtained.

The importance of the invention is no doubt very great. The size of the embrasures, always welcome targets for the enemy's fire, is reduced to a minimum, viz,, the bore of the gun. Of the latter, consequently, only the muzzle, or a small part of the muzzle hoop, may be hit, if the latter by excessive lateral

pointing projects somewhat outward out of the socket-joint. The gunners are perfectly protected against shell, and against shrapnel a cover of sufficient strength may easily be provided. The stability of the gun also greatly facilitates serving it, fewer gunners being required. The gun, finally, requires less space. The invention is of special importance for casements. The accumulation of smoke which hitherto has made, after a few rounds, a prolonged stay in the casements insupportable, and required a special construction for taking off the smoke, is prevented, for the smoke must remain outside.

The printed *resume* of the trials hitherto made with the armored gun, states as follows: "The possibility of rapid firing as well as the complete cover provided for the gun and gunners, render armored guns perfectly indispensable for coast, fortress, and naval artillery; and even the artillery of the besiegers will have to make use of armored batteries of this system, in order to compete with the armored guns of the besieged. Of course, the armor provided for siege batteries must be easily taken to pieces and transported." This is nothing less than iron armor for besieged and besiegers, or a complete revolution of the mode of carrying on sieges, and of constructing fortifications.

Extensive trials are to be made shortly with a 15 centimetre (6-inch) gun, to which also the chief German officers are to be invited. At the same time experiments are to be carried on *against* armored guns, for the purpose of determining what chances there are for the besieger of disabling a gun thus protected.

Should the new construction be found efficient also for heavy guns, the advantages to be gained by its introduction will be reaped again by the cast-steel foundry of Herr Krupp; for only his (the Broadwell) system of gun and his material can be used in the construction. His system: that of breechloading in opposition to muzzle-loading, as still patronized by England. His material: cast-steel, because the other materials for ordnance are not equal to the strain exerted on the barrel of the gun as required by the system of armored guns. We need scarcely say we do not fully share the opinions expressed by our contemporary.

With the introduction of the armored gun, consequently, an obstacle would be placed in the way of those who still desire to employ another material than cast-steel in the building up of guns.

BOOK NOTICES.

AN ELEMENTARY TREATISE ON THE DIFFERENTIAL CALCULUS. By BENJAMIN WILLIAMSON, M.A. London: Longmans, Green & Co. For sale by Van Nostrand. Price $5.25.

This is the third edition of this excellent work. As a text-book it takes the foremost rank.

A chapter on Roulettes, and a note on the Cartesian Oval, are among the additions to the former editions.

LES TERRES DU CIEL. PAR CAMILLE FLAMMARION. Paris: Libraire Academique, Didier Co. For sale by D. Van Nostrand. Price $4.00.

This work is similar in character to the well known "Heavens" by Guillemin.

All the latest discoveries regarding the different planets or planetoids of the solar system, are presented in an attractive form. The illustrations although fewer in number than in other works of its class, are excellent in character, and abundant enough for the purpose.

The volume is a royal octavo of six hundred pages.

A TEXT BOOK ON SURVEYING. For the use of the Cadet Midshipmen at the U. S. Academy. New York: D. Van Nostrand. Price $2.00.

This work is a production of the joint labor of several naval officers of the departments of Astronomy, Navigation, and Surveying, of the U. S. Naval Academy, at Annapolis. It is designed especially for a text book in that institution, and consequently will prove of value to students elsewhere, only so far as certain specialties of surveying, incident to inland work, are better treated here than in most surveying text-books.

The subjects presented are, in their order: The Instruments; Bases; Triangulation; Plotting the work; Determination of heights; Hydrographical Surveying; Tidal Observations; Tides; Practical Hints; Projections; Running Survey; The Portable Transit; The Zenith Telescope.

As a supplement to the treatises on Land Surveying, this work will prove exceedingly valuable in scientific schools.

Such topics as Triangulation, the adjustment and use of the Zenith, and the Portable (astronomical) Telescope, Tidal observations, and Projections of Geodesic Surveys, are valuable to all surveyors, and are nowhere else so consisely yet thoroughly treated.

PRACTICAL TREATISE ON THE PROPERTIES OF CONTINUOUS BRIDGES. By CHARLES BENDER, C. E. New York: D. Van Nostrand. Price 50 cts.

This is the most recent addition to the Science series (No. 26.) Mr. Bender was the author also of No. 4, "The Proportions of Pins used in Bridges."

The present work was produced under circumstances explained in the preface, by the author himself, as follows:

"A paper by the author, being a critical examination into the merits of continuous girders, was prepared six years ago, but its presentation to the American Society of Civil Engineers was delayed till last spring. In this paper the subject for the first time is found to be based without the use of higher calculus on one simple geometrical relation, forming the connecting link between single spans and continuous bridges.

"The same paper, increased with further data resulting from its discussion, is compiled in the short treatise now presented.

"It is hoped that it may contribute to clear opinions as to the real merits of the systems of single and continuous spans, and would lead

to a more thorough understanding of the nature of each.

"The subject having never before been treated in this light, it is believed that railroad engineers will not unfavorably receive the results of special studies which have occupied a period of many years, and which in the main are:

"That in addition to the sensitiveness of continuous bridges, the economy claimed for them does not exist theoretically or practically in all instances in which the construction of properly designed compound single span trusses is not limited as to their depths. As a result of these conclusions, there would seem to be one more good reason that the most valuable time of polytechnic students should not be unnecessarily wasted by entering deeply into a theory which more essentially is of mathematical and historical interest."

INFLUENCE OF FIRE ARMS UPON TACTICS. Translated from the German. By Captain E. H. WICKHAM, R. A. London: H. S. King & Co. For sale by D. Van Nostrand. Price $3.75.

This work the author assures us was suggested by the campaign of 1870.

The history of the introduction of fire arms is carefully detailed, and the evolution of modern practice as carefully considered. How modern infantry was brought into use by the previous introduction of cannons; how small arms then completely assumed the lead, and determined both the methods, as well as the forms of fighting, and how for the first time the guns, in the Franco-German war, exercised an influence which may be said to have carried everything before it, owing to the combination of accuracy, range, and complete command of the most varied topography, by extensive use of shells. All this is narrated in a manner which will elicit much attention from outside the circle of military students for whom it is ostensibly prepared.

THE NEW FORMULA OF MEAN VELOCITY OF DISCHARGE OF RIVERS AND CANALS. By W. R. KUTIER. London: E. and F. N. Spon. 1876. For sale by D. Van Nostrand. Price $5.00.

The work of which this is a translation appeared originally as a series of articles in the *Cultur-Ingenieur*, and has been translated by Mr. L. D'A. Jackson, A.I.C.E. It concerns an important branch of hydraulic engineering in which we are in this country considerably behind the time, although, especially in India and in some of our colonial possessions, much has been and more remains to be done in creating and improving means of water transit, both as regards rivers and canals. Notwithstanding this, the velocity formulae now in use are admittedly faulty, and have been set aside on the Continent by the results of more recent experiments. These are substituted in the present work, and they are now presented in an English dress, with several improvements in arrangement and in other respects.—*Iron.*

LECTURES ON MINING. By J. CALLON, Inspector General of Mines. Translated by C. LE NEVE FOSTER and W. GALLOWAY. London: Dulau & Co. For sale by D. Van Nostrand. Price of vol. 1 and Atlas, $13.00.

Of this extensive work, only the first volume is yet complete. The lectures were prepared for the School of Mines at Paris. The author, Mr. Callon, who died some years since, has enjoyed for many years a high reputation for his proficiency in both theoretical and practical science. His connection with the mining schools as a professor, began in 1839 with the Ecoles des Mineurs of Saint Etienne.

Volume First, of his great work, has just appeared. Volume Second has been published in France, but is not yet translated. Volume Third is in course of preparation by a former pupil of the late author.

The contents of volume one are: Definitions and Introduction; Various Examples of Deposits; Prospecting and Explanatory Workings; Boring; Breaking Ground; Machinery for Breaking Ground; Timbering and Walling; Supporting Special forms of Excavations; Excavations in Watery Strata; Laying out, Opening and Working a Mine; Various Methods of Working.

An Appendix is devoted to descriptions of the large Atlas of Plates.

MISCELLANEOUS.

THE entire population of Asia, is larger by about twenty-five millions than the estimate given in last year's issue of Behm and Wagner's work. The increase mainly falls upon the East India Islands and Anam, the figures in the case of the latter being more than double those given in the tables of last year—viz., twenty-one millions. The population of British India is rather less than last year, being 188,093,700, that of British Burmah being about 2,750,000, including tributary or protected States. The whole population of British India is close on 239 millions. In a map of India, which accompanies the work, the varying density of the population in India is shown—from five inhabitants to over 750 per square mile. The greatest density is found, of course, about Calcutta, as also in patches all along the East coast, and over all the North-west provinces. The population of China is given as 405 millions, with 28½ millions of outlying people. Hong-Kong seems to have decreased by upwards of 2,000 since last year, the number now given being 121,985. Japan is set down as 33,299,014. With regard to Africa, the population of Algeria was, in 1875, estimated to be 2,448,961. The population of Egypt shows a slight increase over last year, being now 17,000,000. The inhabitants of Port Said now number 9,650, and of Ismailia 3,779. Many details are given concerning the area and population of the Soudan and Central and West African States, the results of recent explorations. The British possessions in South Africa, show an increase of territory and population, the latter numbering according to the latest data, 1,338,702. According to latest statistics, the whole population of Australia amounts to 1,867,000; of New Zealand to 421,326. In the Fiji Islands the native popu-

lation seems to be rapidly decreasing. It is calculated now not to exceed 70,000, while the whites, who in 1872 numbered 2,940, were last year only 1,650.—*Engineering.*

NEW STEAM EXCAVATOR.—Messrs Alexander Chaplin & Co., of the Cranstonhill Engine Works, Glasgow, have just constructed a very powerful "steam navvy" or excavator, which they have been exhibiting under steam, in their premises, during the past week. The frame is entirely of malleable iron, with angle irons welded at the corners, plated with 9-16 plates, and weighs 4½ tons. Underneath the frame are two steel axles, each having four wheels, the outside ones double flanged for the purpose of working the machine, and the inside ones single flanged, so as to go on a 4 foot 8½ inch railway guage. The front part of the machine is supplemented by two wings, one on either side, having screws so as to give lateral stability to the machine, when the digger is required to work at right angles to it. The motive power consists of a pair of 8 inch cylinders of the inverted type, with pinion and crank shaft, working into a larger wheel in the barrel, which is grooved to receive the chain. Near the front of the machine is a very strong cast iron column, round which the jib, which is of malleable iron, is made to revolve for one-half of a circle. Two men are required to work the machine, one having entire charge of the engine for hoisting and slewing, and the other man who stands upon a little platform, regulates the out and in motions of the digger. This latter, by the use of a friction clutch and friction brake, has the entire control of pushing the digger out and in to the material to be excavated. Simultaneously with the hoisting or shoving out action, the bucket or spoon is drawn by pitch chain wheels, and it scrapes up the face of the bank, taking a cubic yard of material at every lift. Alongside the machine there must be accommodation rails for the wagons to come and receive the soil; and as soon as the bucket is filled, it is slewed round by the attendant at the engine, either to the one side on the other, right over the empty wagons, and a trigger being drawn, the contents of the bucket fall into the wagon. While the bucket is returning to the working place, it shuts automatically at the bottom, and so is prepared to rake up another fill. The frame is long, broad, and remarkably stable, and by having placed on one end of it the boiler and engines, and at the other the jib, gear and bucket, the whole machine presents the appearance of being admirably balanced, and certain to sit like a rock with an immense strain upon it. The machine is of such a size that it will carry a cutting down to a depth of twenty feet while it is stationed in one level, and it is calculated that by its use the labor of eighty men will be superseded. The one exhibited last week has been built for a limestone quarry near Edinburgh, where it will be employed in tirring off the strata overlying the limestone.

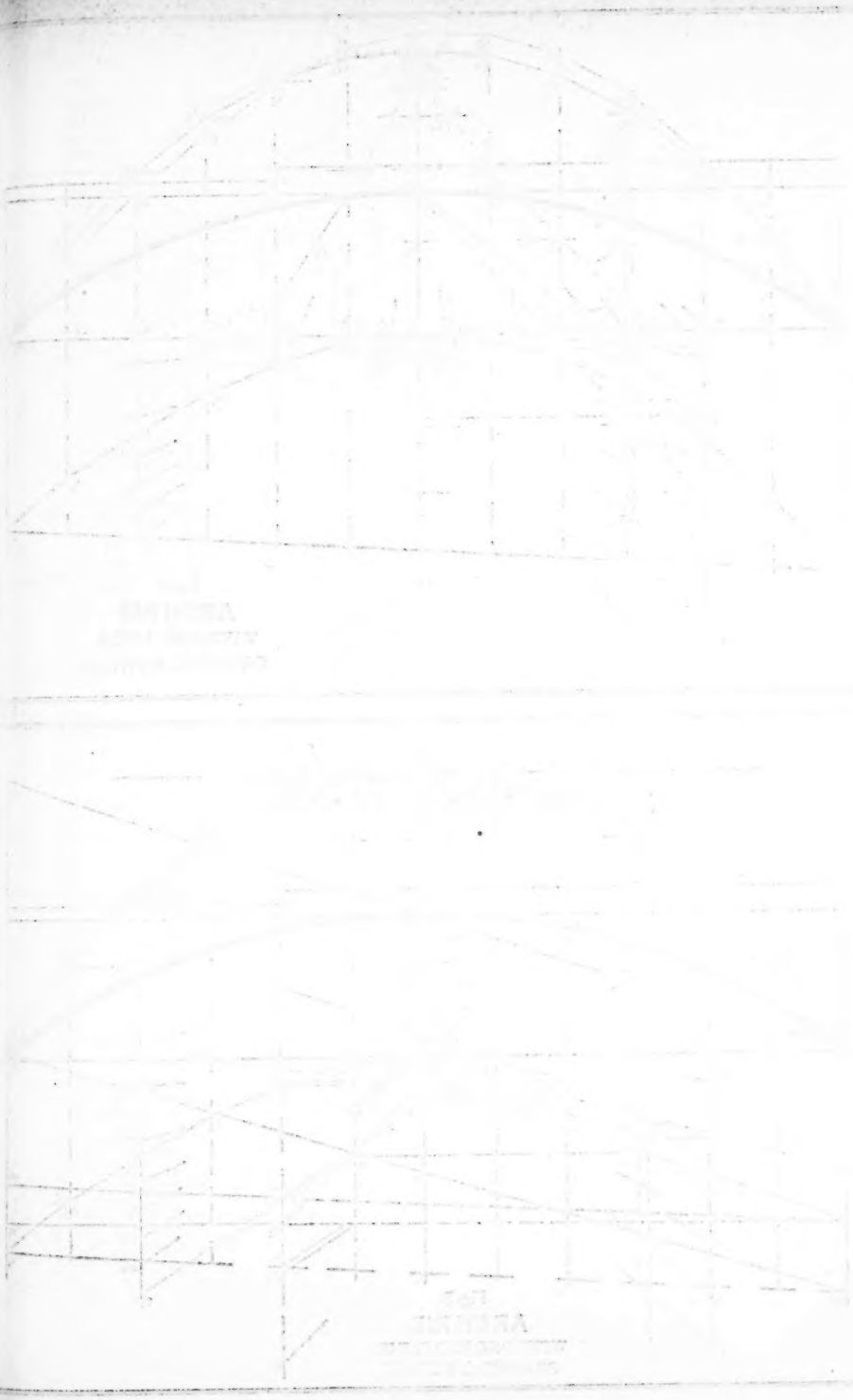
LA COMPAGNIE DU GAZ PARISIEN, previous to constructing some large gasometers near Paris, experimented on the different materials to be used in their construction; among others, on the cement which was to be used for the vertical walls of the reservoirs (*cuves*), with the following results: The cement used was Portland cement of Pouilly in Burgundy. It was found that a brick of pure cement six weeks old, which had been kept in water during that time, broke under a tensile strain of 170 lbs. to the square inch, 12 kilos. per square centimeter; but a brick six months old, which had also been kept under water, broke under a strain of 441 lbs. per square inch, 31 kilos. per square centimeter; that cement hardens more rapidly, when exposed to the sunlight and fresh air, than when affected by humidity; but that this is at the expense of the tenacity and impermeability of the product; hence masonry walls should be sprinkled regularly until the cement has set; that the degree of fineness has an effect on the setting of cement, and consequently upon its ultimate tenacity, for it is a rule that the tenacity is in inverse proportion to the rapidity of the setting; that a mortar made of two parts sand to one of cement broke under a strain of 277 lbs. to the square inch, 19 kilos. per square centimeter, while a mortar of equal parts of sand and cement broke under a strain of 427 lbs. to the square inch, 30 kilos. per square centimeter. The effect of sand upon the shrinkage was shown by the fact that pure cement was defaced by cracks a little more than a foot apart; when mixed with equal parts of sand, the cracks were little more than a yard apart; when three parts of sand to one of cement were used, there were no cracks at all: hence it was this mixture that was used in constructing the reservoirs.

BELLS—The following list of the reputed weights of some of the most noted bells in the world is taken from the *Manufacturer and Builder:—*

	Tons.	Cwts.	Qrs	Lbs.
The Great Bell at Moscow...	198	2	1	0
St. Juan's (also Russian)	80	0	0	0
St. Juan's (also Russian).....	57	1	1	16
The Great Bell at Pekin.....	53	11	1	20
Bell at Nankin.....	22	6	1	20
Bell at Olmutz.....	17	18	0	0
Bell at Vienna, dated 1711...	17	14	0	0
Bell at Notre Dame, Paris, 1680.....	17	0	0	0
Bell at Erfurt (the finest bell-metal extant).....	13	15	0	0
Bell at Montreal.....	13	10	0	0
Great Peter, York Minster, 1845.....	10	15	0	0
Great Tom, Oxford	7	11	3	4
Great Tom, Lincoln.....	5	8	0	0
Dunstan, Canterbury.....	3	10	0	0

The Montreal bell was cast by the founders of the Great Peter of York, the Great Tom of Lincoln, and the Dunstan of Canterbury.

REDUCTION OF COAL FREIGHTS ON THE TAFF VALE RAILWAY.—The directors of this company have issued a circular announcing a reduction of freight on coal to a considerable extent, so much so that to some freighters it will make a difference of £3,000 to £4,000 a year.



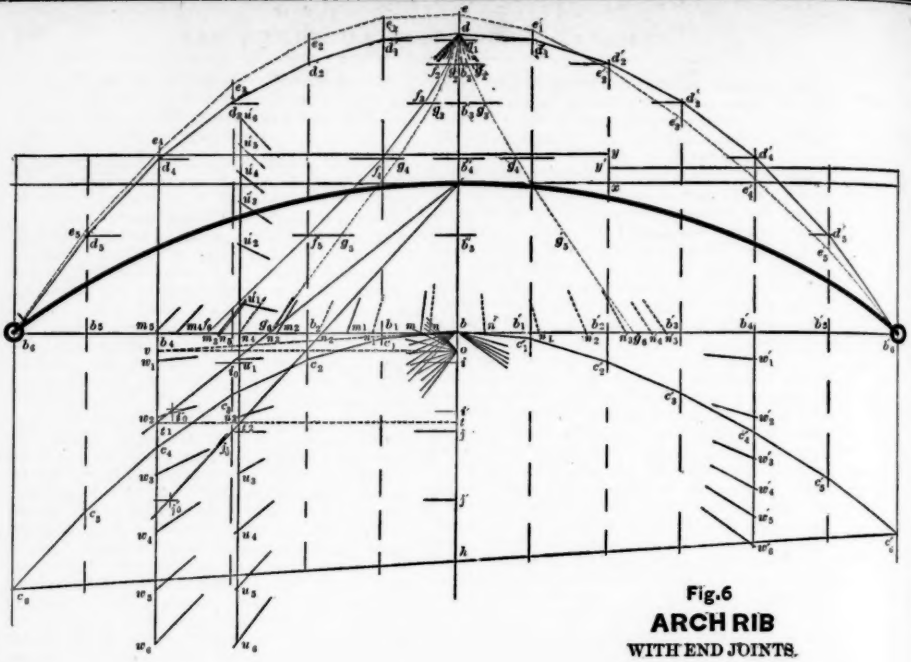


Fig.6

ARCH RIB

WITH END JOINTS.

GRAPHICAL METHOD.

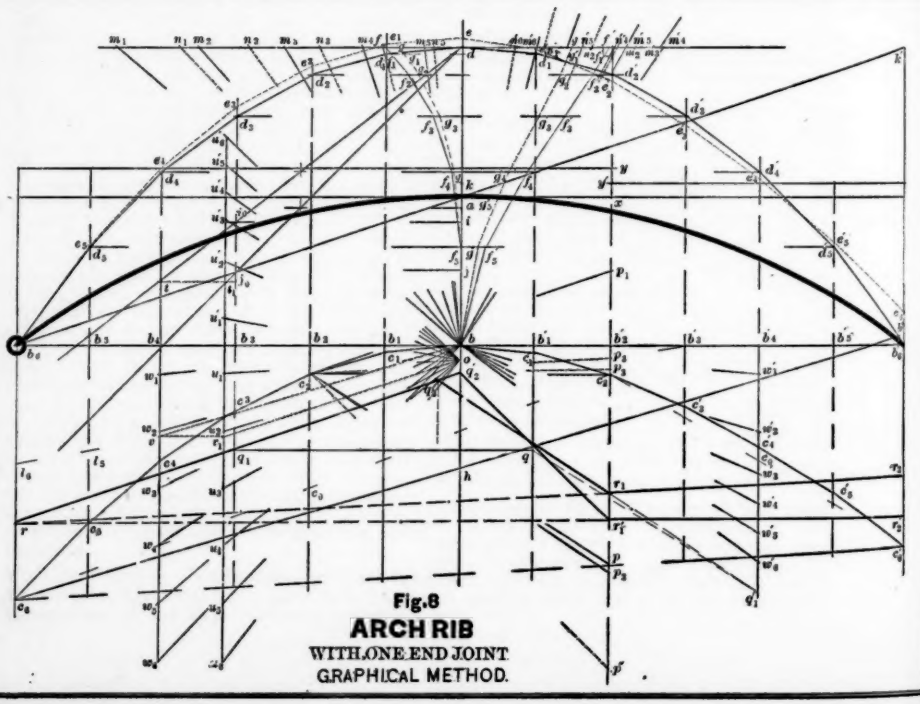


Fig.8

ARCH RIB

WITH ONE END JOINT

GRAPHICAL METHOD.

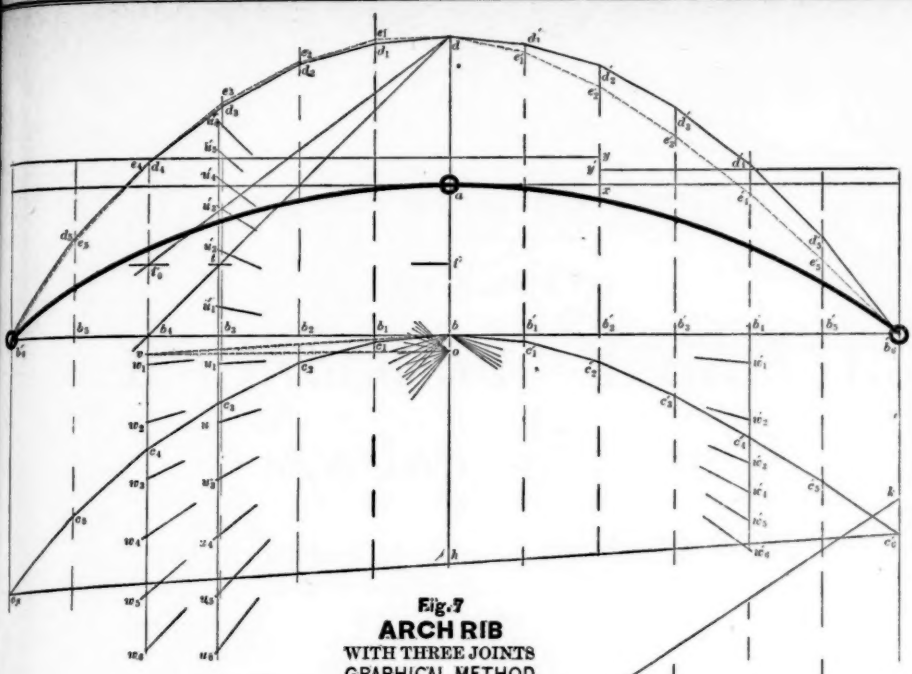


Fig.7
ARCH RIB
WITH THREE JOINTS
GRAPHICAL METHOD.

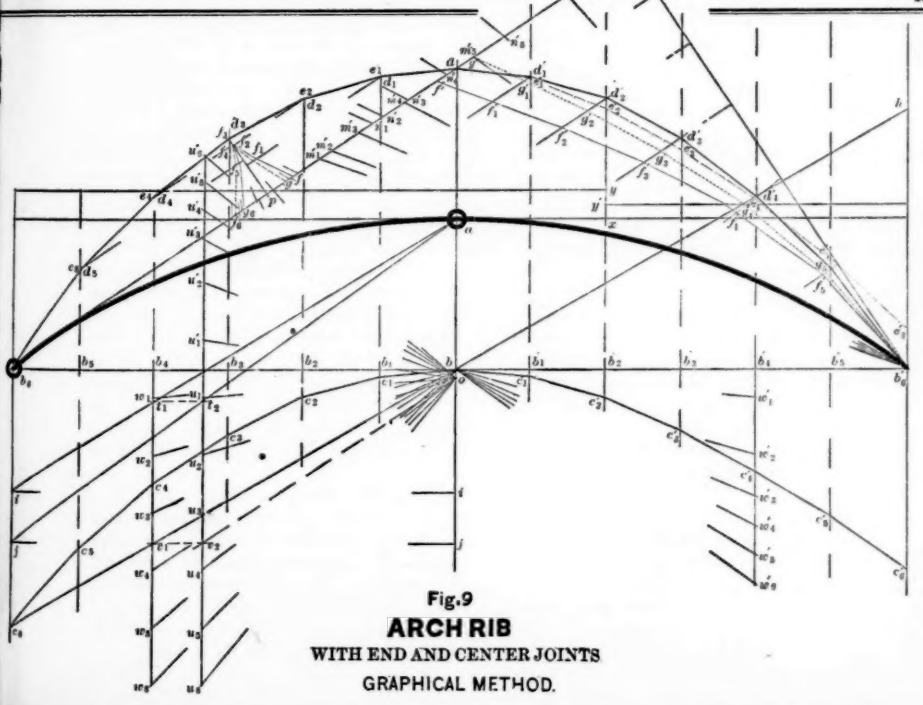


Fig.9
ARCH RIB
WITH END AND CENTER JOINTS
GRAPHICAL METHOD.